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Freight Train Noise & Vibration Assessment

Bibra Lake (North), Bibra Lake (North-East) & South Lake (North)

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1 INTRODUCTION

The City of Cockburn are undertaking The Lakes Revitalisation Strategy Scheme Amendment, covering the areas shown in *Figure 1-1*, being in the suburbs of North Lake, Bibra Lake and South Lake. This report focuses on the areas of Bibra Lake and South Lake, in relation to the potential noise and vibration impacts associated with the freight train line. The proposed density and zonings in the areas of interest are shown in *Figures 1-2 & 1-3*.

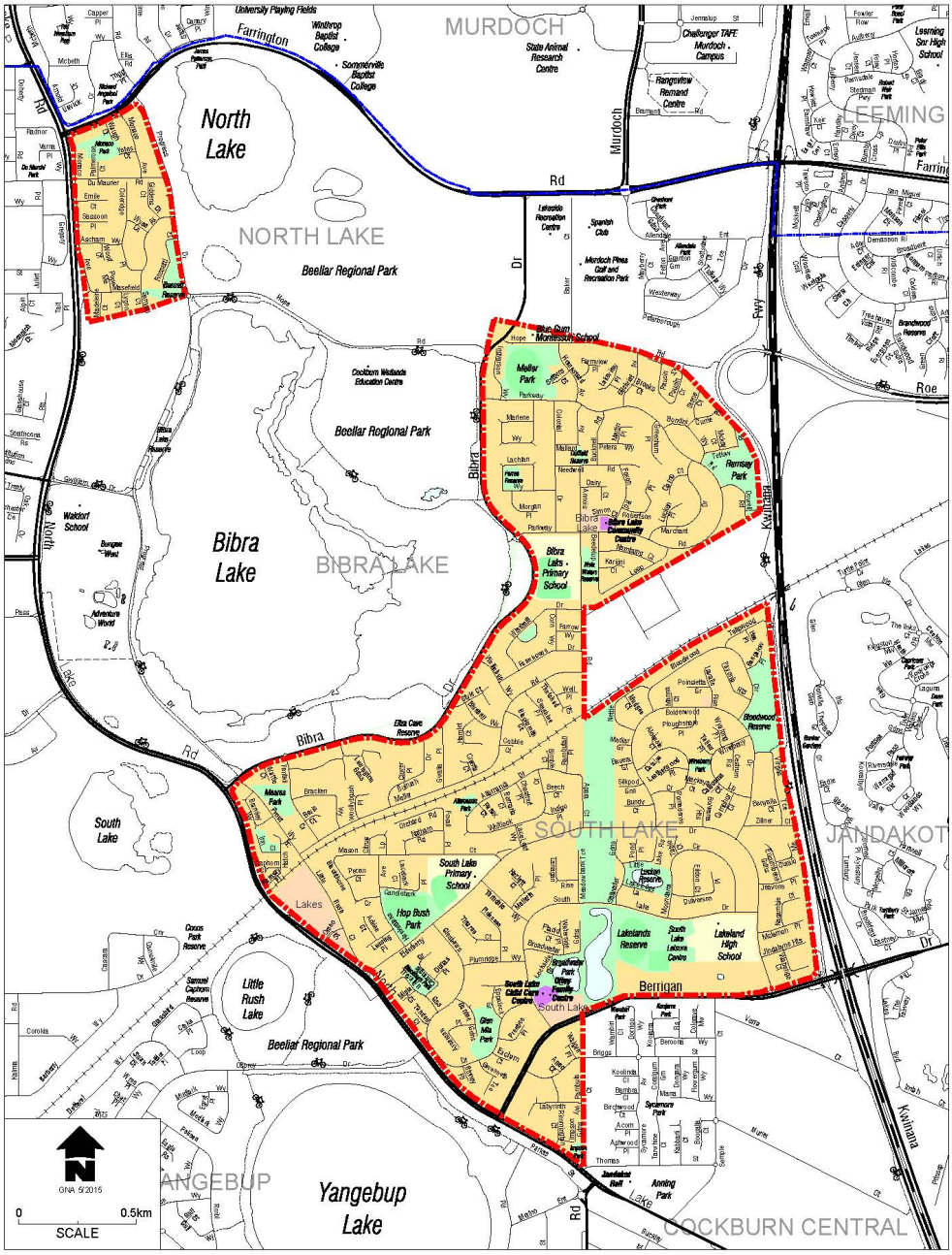


Figure 1-1 The Lakes Revitalisation and Scheme Amendment Area

Figure 1-2 Proposed Density and Zoning for Bibra Lake (North)

Figure 1-3 Proposed Density and Zoning for Bibra Lake (North-East)

The zoning remains residential, but increases in density nominally from R20 increasing to R30 in Bibra Lake, R40 in South Lake and some small areas of R60 & R80. *Figure 1-4* shows the implications of the new density codes. For R20, R30 and R40, single storey or double storey dwellings are permitted whereas R60 may be three storeys and R80 four storeys and potentially higher.

R-Code	Dwelling Type	Minimum site area per dwelling (m2)
R20	Single house* or grouped dwelling**	Min 350 Ave 450
	Multiple dwelling	450
R25	Single house or grouped dwelling	Min 300 Ave 350
	Multiple dwelling	350
R30	Single house or grouped dwelling	Min 260 Ave 300
	Multiple dwelling	300
R35	Single house or grouped dwelling	Min 220 Ave 260
	Multiple dwelling	260
R40	Single house or grouped dwelling	Min 180 Ave 220
R50	Single house or grouped dwelling	Min 160 Ave 180
R60	Single house or grouped dwelling	Min 120 Ave 150
R80	Single house or grouped dwelling	Min 100 Ave 120

Figure 1-4 Implications of Different Residential Densities

By changing the density has the potential to encourage redevelopment. As an example, 11 Thatched Court currently has a single storey dwelling on a 788m^2 lot, which is the maximum number of dwellings for the lot size under R20 Coding. Under the R30 coding, it is permitted to have 2 single, grouped or multiple dwellings.

The expectation is that the redevelopment will occur over a number of years. The focus of this report is to define noise and vibration affected areas, based on recent noise and vibration measurements, prior to any further development occurring. The purpose of this will allow City of Cockburn to identify lots that are affected and provide deemed to satisfy (DTS) construction packages for redevelopment of the site as development applications are submitted. Alternatively, site specific assessments may be requested by City of Cockburn or may be undertaken by the developer rather than adopting the DTS standard.

Appendix B contains a description of some of the terminology used throughout this report.

2 CRITERIA

Section 2.1 and 2.2 provide the noise and vibration criteria respectively, that have been used in this project.

2.1 Noise Criteria

Noise from transportation corridors is assessed against the *State Planning Policy 5.4 Road and Rail Transport Noise and Freight Considerations in Land Use Planning* (hereafter referred to as SPP 5.4) produced by the Western Australian Planning Commission (WAPC). SPP 5.4 (refer *Section 2.1.1*) uses the L_{Aeq} parameter to assess the noise impacts, which is a logarithmic average of noise levels over time. For road traffic and passenger rail noise, this parameter is considered to adequately capture the potential noise impacts. Freight trains on the other hand are discrete events throughout the day and therefore the L_{Aeq} value may not represent the actual noise impact.

Early drafts of the SPP contemplated the inclusion of a maximum noise level criteria (L_{Amax}) for freight trains, however this was removed during stakeholder consultation. Lloyd George Acoustics undertook a study for the Freight and Logistics Council of Western Australia (FLC)[1] that considered the L_{Amax} parameter. This report combines both the L_{Aeq} criteria of SPP 5.4 and the L_{Amax} criteria of the FLC study, with these discussed in *Sections 2.1.1 and 2.1.2* respectively.

2.1.1 State Planning Policy 5.4

The objectives in SPP 5.4 are to:

- Protect people from unreasonable levels of transport noise by establishing a standardised set of criteria to be used in the assessment of proposals;
- Protect major transport corridors and freight operations from incompatible urban encroachment;
- Encourage best practice design and construction standards for new development proposals and new or redevelopment transport infrastructure proposals;
- Facilitate the development and operation of an efficient freight network; and
- Facilitate the strategic co-location of freight handling facilities.

SPP 5.4's outdoor noise criteria are shown in *Table 2-1*. These criteria apply at any point 1-metre from a habitable façade of a noise sensitive premises and in one outdoor living area.

Table 2-1 Outdoor Noise Criteria

Period	Target	Limit
Day (6am to 10pm)	55 dB $L_{Aeq(Day)}$	60 dB $L_{Aeq(Day)}$
Night (10pm to 6am)	50 dB $L_{Aeq(Night)}$	55 dB $L_{Aeq(Night)}$

Note: The 5 dB difference between the target and limit is referred to as the margin.

[1] *Freight Train Noise Assessments*; Reference: 14113026-02 Final, 14 September 2015.

In the application of these outdoor noise criteria to new noise sensitive developments, the objectives of SPP 5.4 is to achieve -

- acceptable indoor noise levels in noise-sensitive areas (e.g. bedrooms and living rooms of houses); and
- a 'reasonable' degree of acoustic amenity in at least one outdoor living area on each residential lot.

If a noise sensitive development takes place in an area where outdoor noise levels will meet the *target*, no further measures are required under SPP 5.4.

In areas where the *target* is exceeded, customised noise mitigation measures should be implemented with a view to achieving the *target* in at least one outdoor living area on each residential lot, or if this is not practicable, within the *margin*. Where indoor spaces are planned to be facing outdoor areas that are above the *target*, mitigation measures should be implemented to achieve acceptable indoor noise levels in those spaces.

For residential buildings, "acceptable indoor noise levels" are taken to be 40 dB $L_{Aeq(Day)}$ in living areas and 35 dB $L_{Aeq(Night)}$ in bedrooms.

The Guidelines to the Policy provide deemed to comply architectural treatment packages based on external noise levels as follows:

- Package A – Applied where external noise levels are 55-60 dB $L_{Aeq(Day)}$ or 50-55 dB $L_{Aeq(Night)}$;
- Package B – Applied where external noise levels are 60-63 dB $L_{Aeq(Day)}$ or 55-58 dB $L_{Aeq(Night)}$;
- Package C – Applied where external noise levels are 63-65 dB $L_{Aeq(Day)}$ or 58-60 dB $L_{Aeq(Night)}$.

The Packages are applied to road traffic as well as passenger and freight trains. From the FLC Study, it was identified that these Packages may not be adequate for freight trains under some circumstances. The main reason for this was the amount of low frequency energy from freight trains, which is significantly higher than that for road traffic or electric passenger trains.

2.1.2 Freight and Logistic Council Noise Criteria

The approach of the FLC Study was to adopt the L_{Amax} criteria put forward in the early SPP drafts as shown in *Table 2-2*.

Table 2-2 L_{Amax} Outdoor Noise Criteria

Period	Target	Limit
Any	75 dB L_{Amax}	80 dB L_{Amax}

Based on the above criteria, the findings of the FLC study were that in most instances, the L_{Amax} criteria were more stringent than the L_{Aeq} criteria.

It should be noted that the L_{Amax} parameter is primarily used to assess sleep disturbance and therefore the L_{Amax} criteria may only be applicable during the night (10pm to 6am) and/or only to bedrooms. As the early SPP 5.4 drafts did not contemplate this, this distinction has also not been made in this report.

The outcome of the FLC study was that a new set of acceptable treatment packages were put forward for developments adjoining freight rail lines as follows:

- Package AF – Applied where external noise levels from freight trains are 75-80 dB L_{Amax};
- Package BF – Applied where external noise levels from freight trains are 80-88 dB L_{Amax}; and
- Package CF – Applied where external noise levels from freight trains are 88-92 dB L_{Amax}.

New packages were required in order to achieve what was deemed an acceptable maximum internal noise level (60 dB L_{Amax}) and ensure compliance with the L_{Aeq} criteria of *Section 2.1*. One of the main changes in the freight packages is to require the use of clay roof tiles. This was necessary in order to economically attenuate low frequency noise associated with freight trains, transferring through the roof/ceiling noise path. Packages AF to CF are provided in *Appendix A*.

The L_{Amax} criteria and associated packages have formed part of the FLC's Bulletin No.7, October 2015. The Bulletin and the Lloyd George Acoustics study have been released by FLC and are publicly available on their website. It is FLC's intention that these documents will help influence and inform Government policy and practice, in relation to freight noise and the protection of freight rail corridors.

2.2 Vibration Criteria

Exposure limits for vibration are normally defined in terms of a multiplying factor that is applied to the base curves defined in AS 2670.2:1990 *Evaluation of Human Exposure to Whole Body Vibration, Part 2: Continuous and Shock Induced Vibration in Buildings (1 to 80 Hz)*. The base curve is the point at which adverse comment is considered rare. The Standard states that at levels above the base curve, vibration may or may not give rise to adverse comment depending on circumstances. The measure of human annoyance within this Report is a velocity (mm/s) root mean squared (rms). The multiplying factors are given in Appendix A of AS 2670.2-1990 as follows for a residential premises:

- Night-time continuous or intermittent vibration – Curve 1.4;
- Daytime continuous or intermittent vibration – Curve 2 to Curve 4;
- Night-time transient vibration with several occurrences per day – Curve 1.4 to Curve 20;
- Daytime transient vibration with several occurrences per day – Curve 30 to 90

It is noted that within residential areas there are wide variations in vibration tolerance. Specific values are dependent upon social and cultural factors, psychological attitudes and expected interference with privacy.

Previous projects within Western Australia have adopted the use of Curve 2 and this has been accepted by the Department of Environment Regulation (DER), with a preference to achieve Curve 1.4 where practicable. Given this project represents infill development, adopting the Curve 2 criteria as a trigger for potential vibration treatments is considered appropriate.

There are no Australian Standards that provide criteria in relation to structural damage to buildings. Structural damage measurements are normally undertaken as peak component particle velocity (PCPV). For instance, for road construction projects Main Roads Western Australia generally adopts a limit of 5mm/s PCPV for structurally sound dwellings. The Curves of AS2670.2 are not relevant for structural damage.

It should be noted that structural damage occurs at significantly higher vibration levels than human perception, so a person will perceive vibration (and potentially be annoyed by it) well before any structural damage is likely to occur.

3 METHODOLOGY

Noise and vibration measurements and modelling have been undertaken in accordance with the requirements of SPP 5.4 and associated Guidelines as described below in *Sections 3.1 and 3.2*.

3.1 Site Measurements

Noise and/or vibration monitoring was undertaken within the study area at 13 residences, noting that 1 Caphorn Close was attended twice – refer *Figures 3-1 & 3-2* and *Table 3-1*.

Table 3-1 Noise and Vibration Monitoring Locations

Dates	Location	Noise	Vibration
19 October to 27 October 2016	17 Allamanda Drive, South Lake	-	Yes
	20 Allamanda Drive, South Lake	Yes	Yes
	37 Meller Road, Bibra Lake	Yes	Yes
	12 Bullrush Drive, Bibra Lake	-	Yes
	6 Ramsay Place, Bibra Lake	Yes	-
27 October to 5 November 2016	15 Bloodwood Circle, South Lake	Yes	Yes
	1 Mudgee Court, South Lake	Yes	-
	10 Orchard Road, South Lake	Yes	-
	2b Blackthorne Crescent, South Lake	Yes	Yes
	1 Caphorn Close, Bibra Lake	Yes	-
5 November to 15 November 2016	15a Sunshine Place, Bibra Lake	Yes	Yes
	11 Citrus Loop, South Lake	Yes	Yes
15 November to 22 November 2016	1 Caphorn Close, Bibra Lake	Yes	Yes
22 November 2016 to 30 November 2016	15 Meller Road, Bibra Lake	Yes	Yes

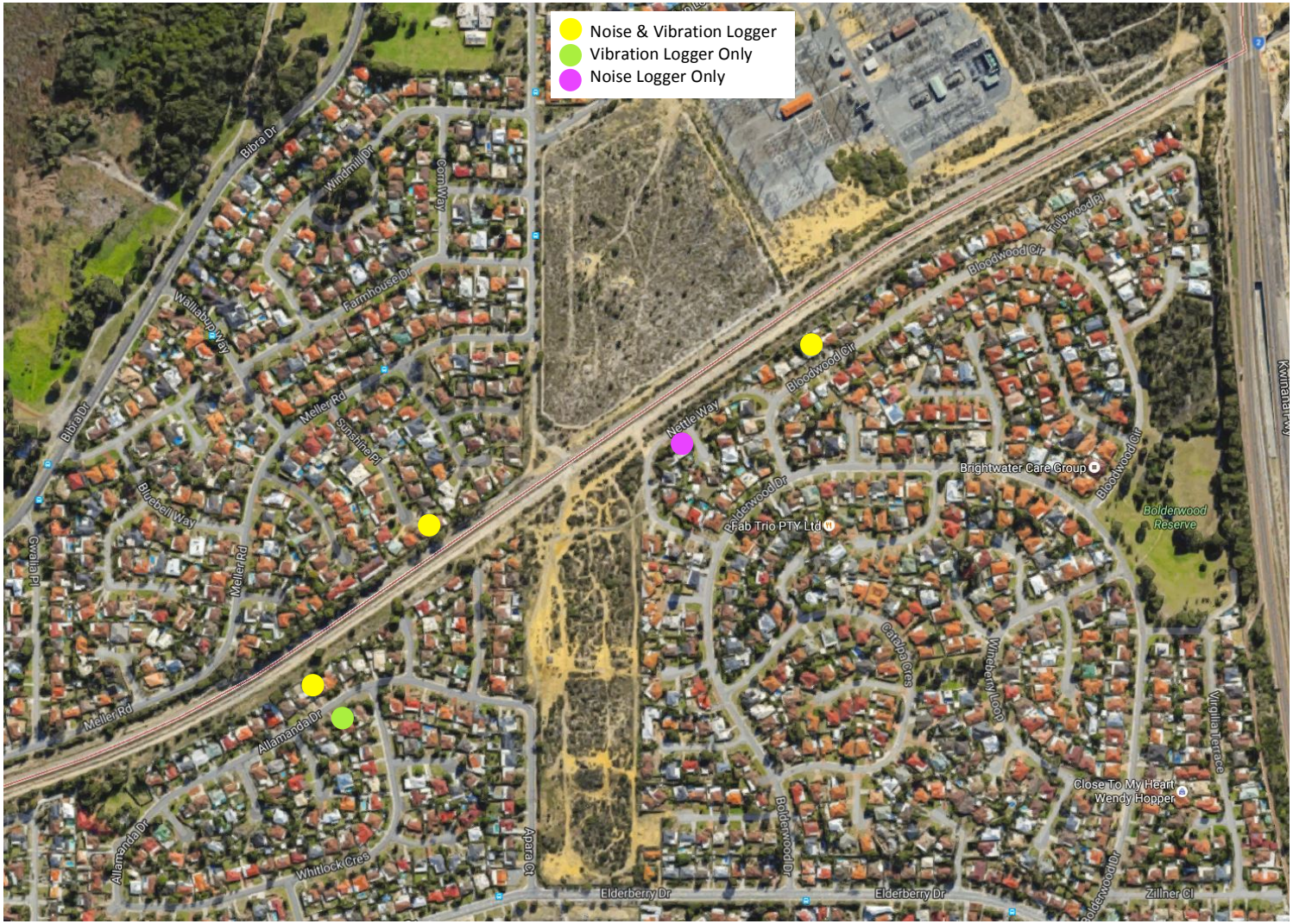


Figure 3-1 Location of Noise and Vibration Monitoring Part 1

Figure 3-2 Location of Noise and Vibration Monitoring Part 2

The locations were selected to provide a reasonable distribution across the study area as well as capturing different topographical conditions, distances from the rail and different orientations (fronting, backing on etc). Once identified, the City of Cockburn obtained consent from the identified locations or where consent could not be obtained, from a suitable alternative.

Noise monitoring utilised Acoustic Research Laboratories (ARL) noise data loggers, where during each measurement session, at least one of the loggers was capable of recording audio (Ngara type logger) in order to assist in train identification. The loggers were programmed to record 5-minute[2] L_{Amax} and L_{Aeq} levels. The loggers were field calibrated before and after the measurement session and found to be accurate to within +/- 1 dB. Lloyd George Acoustics also holds a current laboratory calibration certificate for each logger, available upon request.

Vibration monitoring utilised Texcel GTM/ETM Vibration Loggers connected to a tri-axial geophone set to 1 or 5-minute intervals. The loggers were set to record the worst-case frequency, peak component particle velocity (PCPV) and the component root-mean-square (rms). Again, Lloyd George Acoustics holds current laboratory certificates of calibration, available upon request.

Once trains are identified within each data set, the average and standard deviation (SD) are determined for the $L_{Aeq,5min}$ and L_{Amax} noise levels. For the L_{Amax}, the average + 1 SD is then used for calibration. The $L_{Aeq,5min}$ average + 1 SD value is converted to $L_{Aeq(Night)}$ on the basis of 1 train per hour and this is then used for calibration.

For vibration, the maximum RMS value of the radial, transverse and vertical direction is determined for each identified train. Again the average + 1 SD are calculated for each location and assessed against the more stringent radial/transverse criteria, even if the vertical was the worst-case, as a conservative approach.

The average + 1SD has been used in the analysis. Selecting a different approach or statistical parameter will vary the analysis. It can be seen from the results that noise and vibration from different trains can vary significantly. For example at one location, the $L_{Aeq,5min}$ varied by 30 dB, the L_{Amax} varied by 40 dB and the vibration varied from Curve 0.8 to Curve 5.2 for the 142 trains measured. Only taking the average of these trains was not considered appropriate, since this would mean that 50% of the trains were louder and therefore would not represent the actual impact. Only taking the maximum of the trains was considered overly conservative. It was decided that the average + 1 SD provided a better reflection on the impacts, without being overly conservative. For the example location, this value aligned approximately with the 90th percentile meaning that 10% of trains would have a higher value but 90% of trains would be at a lower value.

3.2 Noise Modelling

The computer programme *SoundPLAN 7.4* was utilised to predict the noise emissions using the *Nordic Prediction Method for Train Noise* (NMT) algorithms. The following options were selected with the model then calibrated against the noise measurements:

- The rail head is assumed to be 0.5 metres above natural ground;
- Temperature, humidity and air pressure are assumed to be 15^{o}C, 70% and 1013.3 mbar respectively;
- Air absorption is in accordance with ANSI 126;
- L_{max} for diesel powered trains option is selected.

[2] Note that the noise logger for 15 Bloodwood Circle was set to record at 15-minute intervals.

Predictions are made at heights of 1.4, 4.4, 7.4 & 10.4 metres above ground, representing ground to third floor noise levels. All houses are modelled as having a height of 3.5 metres with standard residential fences located based on *GoogleEarth* imagery. The terrain for the area is 3D and was obtained from Landgate. A sample image of the noise model is shown in *Figure 3-3*.

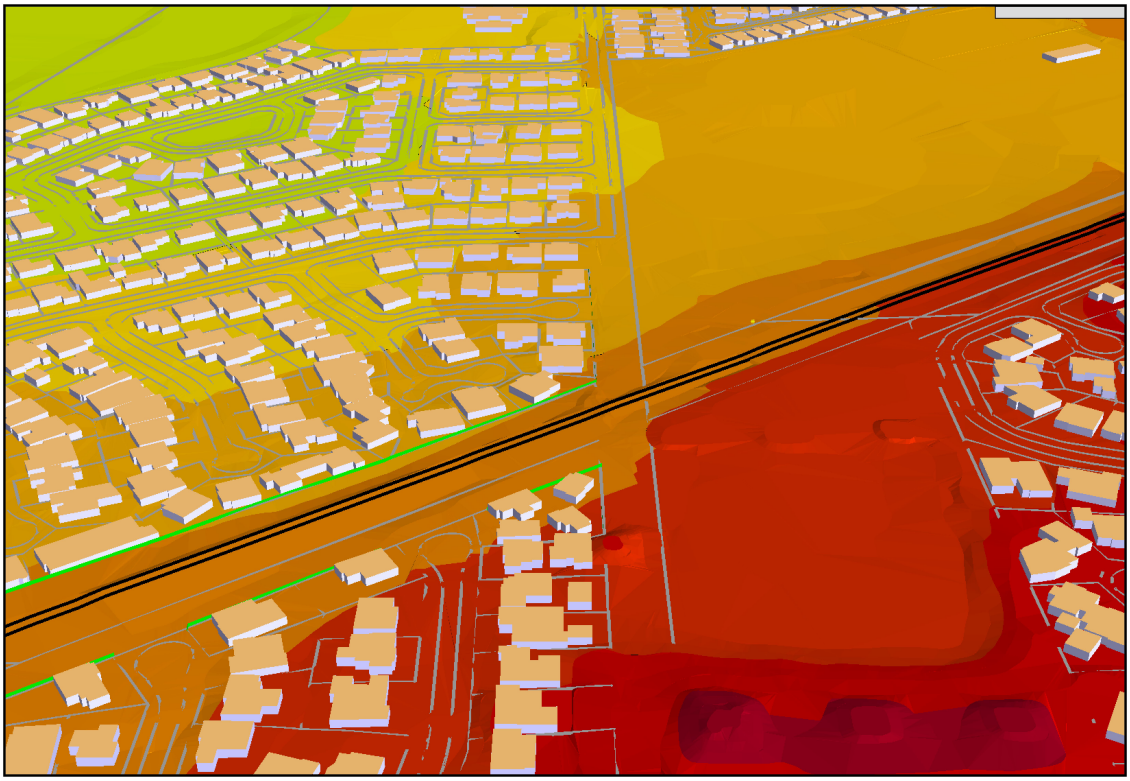


Figure 3-3 Image of 3D Noise Model

4 MONITORING RESULTS

Table 4-1 provides a summary of the number of train passes identified on the noise and vibration loggers. Whilst in some cases, noise and vibration monitoring occurred simultaneously, the numbers might be different as a battery may have failed reducing the amount of recorded data (e.g. 15A Sunshine Place). Nevertheless, a high number of train passbys were obtained at each location.

Table 4-2 provides a summary of all the measurement results, with *Sections 4-1 to 4-13* providing further detail.

Table 4-1 Number of Noise and Vibration Samples

Location	Noise Monitoring			Vibration Monitoring
	Total Trains Identified	Typical Numbers of Trains Per Day		Total Trains Identified
		Day (6am to 10pm)	Night (10pm to 6am)	
17 Allamanda Drive, South Lake	N/A	N/A	N/A	141
20 Allamanda Drive, South Lake	139	14	6	145
37 Meller Road, Bibra Lake	142	14	6	139
12 Bullrush Drive, Bibra Lake	N/A	N/A	N/A	136
6 Ramsay Place, Bibra Lake	139	14	6	N/A
15 Bloodwood Circle, South Lake	181	14	7	172
1 Mudgee Court, South Lake	177	15	7	N/A
10 Orchard Road, South Lake	177	15	7	N/A
2b Blackthorne Crescent, South Lake	181	15	7	194
1 Caphorn Close, Bibra Lake	132	15	7	N/A
15A Sunshine Place, Bibra Lake	76	20	7	273
11 Citrus Loop, South Lake	269	21	8	270
1 Caphorn Close, Bibra Lake	129	19	9	130
15 Meller Road, Bibra Lake	195	19	7	194

Table 4-2 Noise and Vibration Monitoring Locations

Location	Distance to Nearest Railway Track (m)	Boundary Fence	Noise		Vibration
			$L_{Aeq(Night)}$, dB	L_{Amax}, dB	AS2670.2 Curve
15 Bloodwood Circle, South Lake	45	Yes	53.9	85.8	1.3
1 Mudgee Court, South Lake	55	Yes	52.8	82.4	-
15A Sunshine Place, Bibra Lake	20	Yes	59.2	88.0	2.8
17 Allamanda Drive, South Lake	90	Yes	-	-	1.8
20 Allamanda Drive, South Lake	35	Yes	56.0	85.2	1.4
12 Bullrush Drive, Bibra Lake	80	Yes	-	-	1.6
37 Meller Road, Bibra Lake	45	No	60.6	87.1	2.7
10 Orchard Road, South Lake	55	No	59.9	88.3	-
11 Citrus Loop, South Lake	30	Yes	53.2	83.0	1.7
15 Meller Road, Bibra Lake	45	No	56.5	84.8	1.6
2b Blackthorne Crescent, South Lake	50	Yes	53.7	86.7	2.1
1 Caphorn Close, Bibra Lake	30	Yes	55.1	88.6	-
1 Caphorn Close, Bibra Lake	30	Yes	55.9	85.0	2.1
6 Ramsay Place, Bibra Lake	30	No	60.9	94.6	-

The above is broadly summarised by plotting the results against the distance from the railway track on *Figures 4-1 to 4-3*.

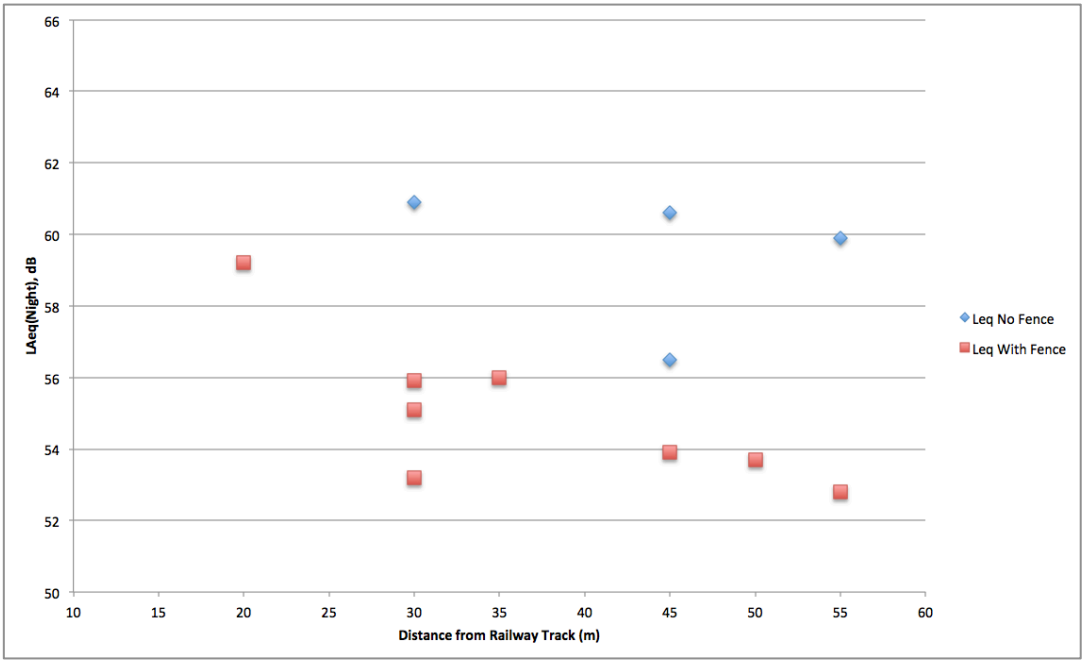


Figure 4-1 Summary of $L_{Aeq(Night)}$ Values at Monitoring Locations

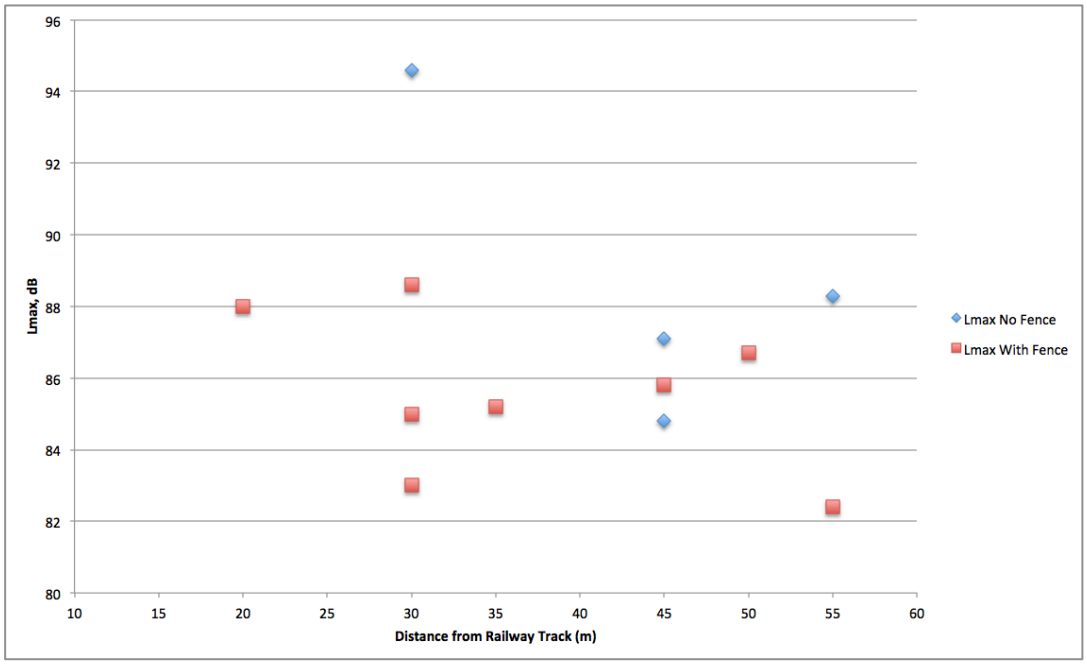


Figure 4-2 Summary of L_{Amax} Values at Monitoring Locations

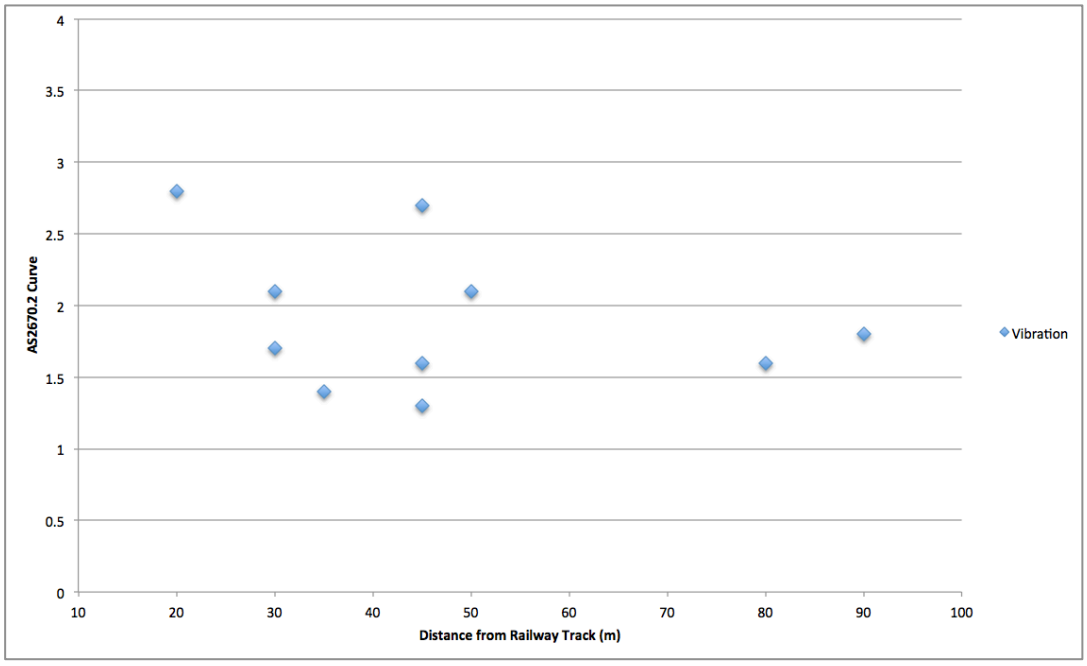


Figure 4-3 Summary of Vibration Values at Monitoring Locations

Whilst there is somewhat of a trend that shows further from the track, noise and vibration levels are less, there are some inconsistencies. This is not surprising when reviewing *Sections 4.1 to 4.13* where the range in values at the same location is significant. Additionally, there are local effects such as those further west are likely to have higher maximum noise levels due to the proximity of the North Lake Road crossing and therefore sounding of horns. Also the rail is in a significant cutting for the locations to the east, close to the Freeway, which will also have an effect.

4.1 15 Bloodwood Circle, South Lake

This location is the eastern most of all monitoring locations and on the south side, with the results summarised in *Figures 4-4 & 4-5*. Note the red point is the average + 1 SD value for the data set. Vibration at this location is relatively low, which may be attributed to the railway being in a significant cut (~ 4m).

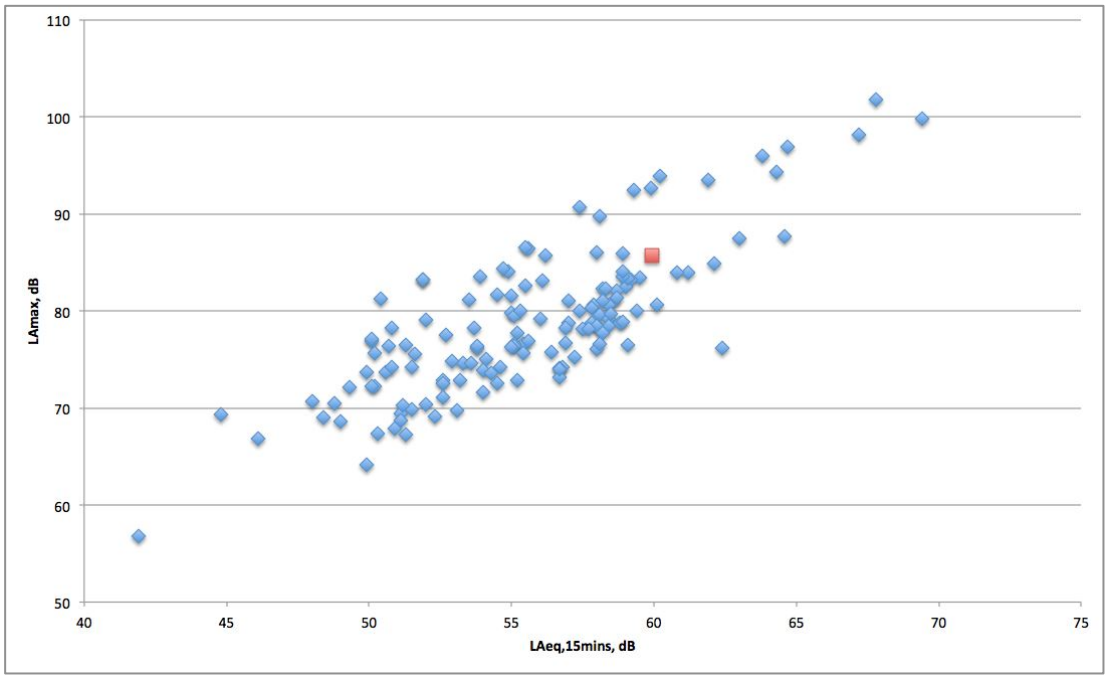


Figure 4-4 15 Bloodwood Circle Noise Measurements

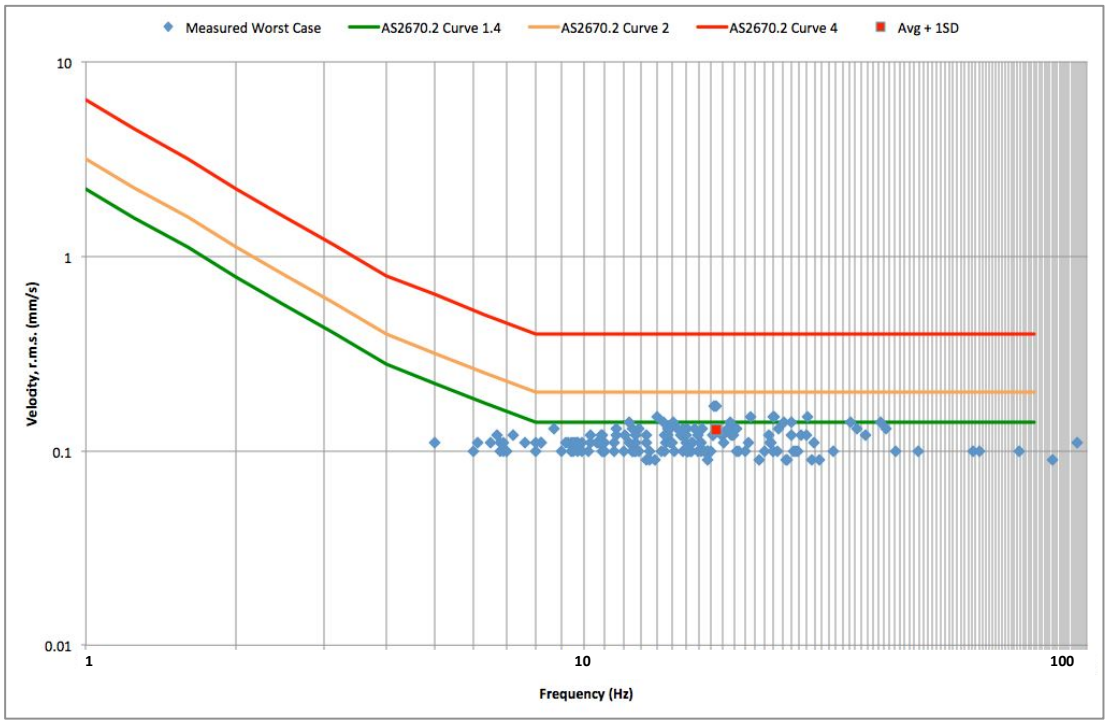


Figure 4-5 15 Bloodwood Circle Vibration Measurements

4.2 1 Mudgee Court

This location is at the eastern end of the study area and on the south side of the track, with the results summarised in *Figure 4-6*. Note the red point is the average + 1 SD value for the data set and only noise monitoring was undertaken at this location.

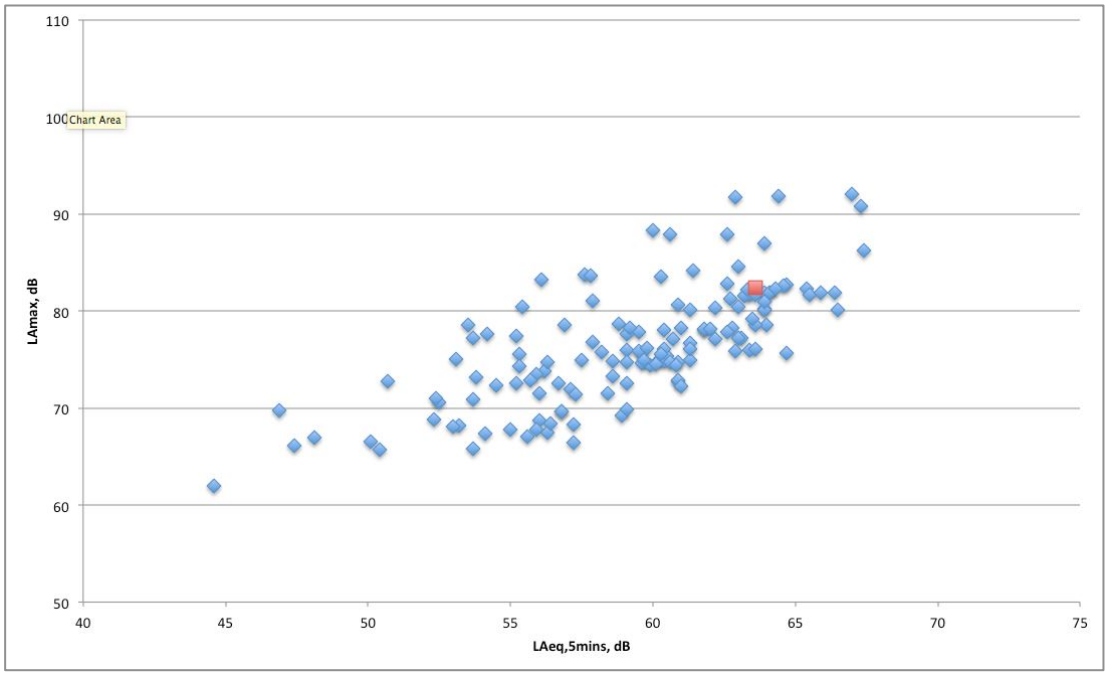


Figure 4-6 1 Mudgee Court Noise Measurements

4.3 15A Sunshine Place

This location is at the eastern end of the study area and on the north side of the track, with the results summarised in *Figures 4-7 & 4-8*. Note the red point is the average + 1 SD value for the data set. Noise and vibration at this location are relatively high, which is expected since this residence is the closest monitoring location to the track at 20 metres.

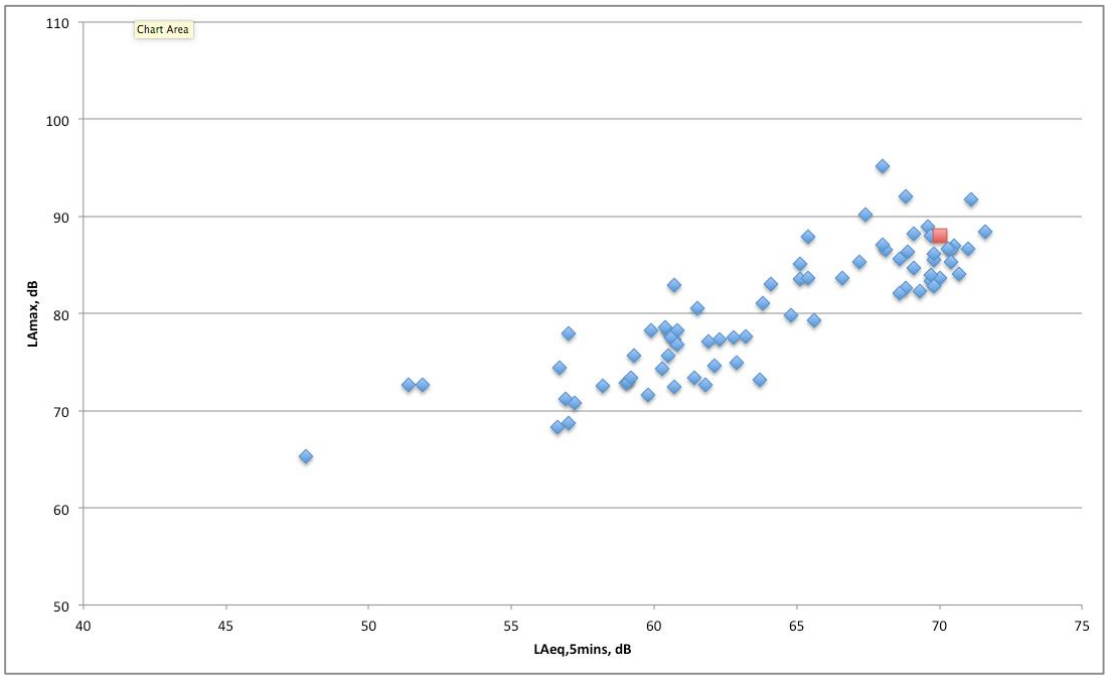


Figure 4-7 15A Sunshine Place Noise Measurements

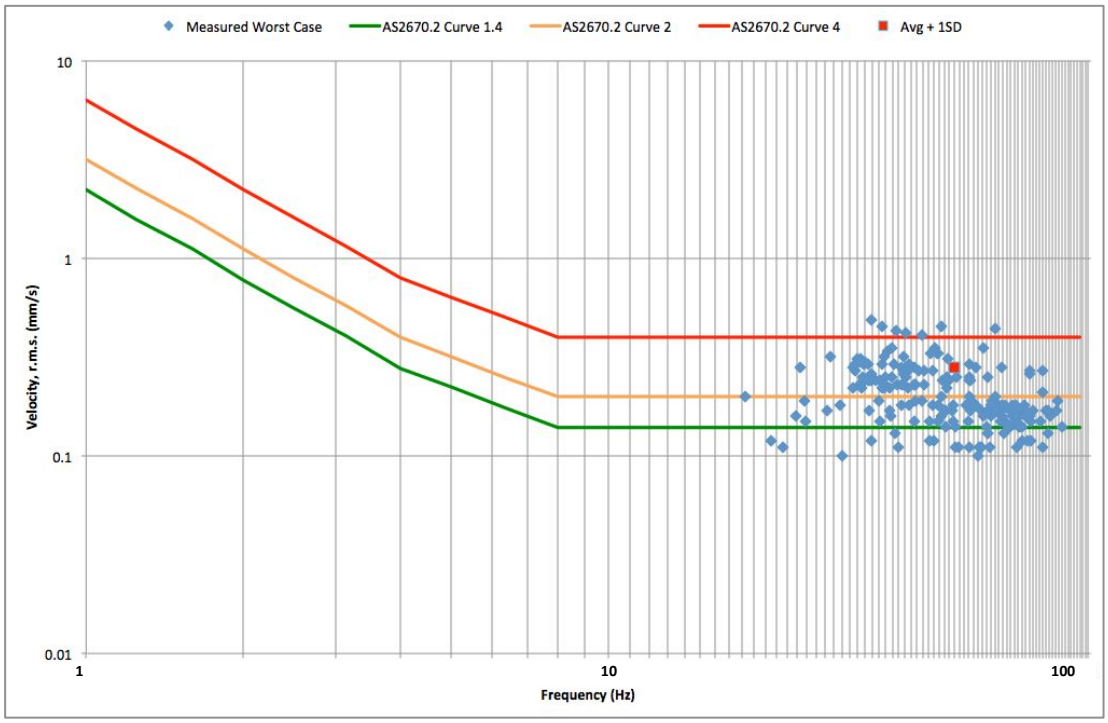


Figure 4-8 15A Sunshine Place Vibration Measurements

4.4 17 Allamanda Drive

This location is central to the study area, on the south side of the track and in the second row of houses. The results are summarised in *Figure 4-9* with only vibration monitoring undertaken. Note the red point is the average + 1 SD value for the data set. Interestingly, vibration levels at this location are slightly higher than those at the closer 20 Allamanda Drive location.

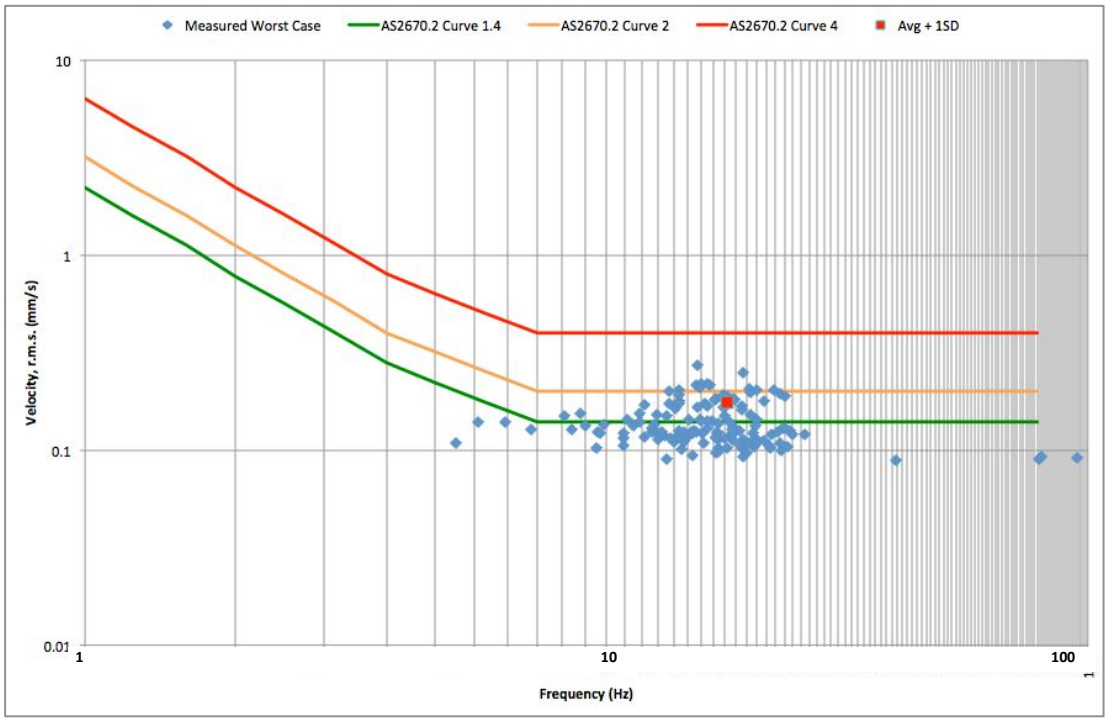


Figure 4-9 17 Allamanda Drive Vibration Measurements

4.5 20 Allamanda Drive

This location is central to the study area, on the south side of the track with the results summarised in *Figures 4-10 & 4-11*. Note the red point is the average + 1 SD value for the data set. Interestingly, vibration levels are lower at this location than at 17 Allamanda Drive, which is further away.

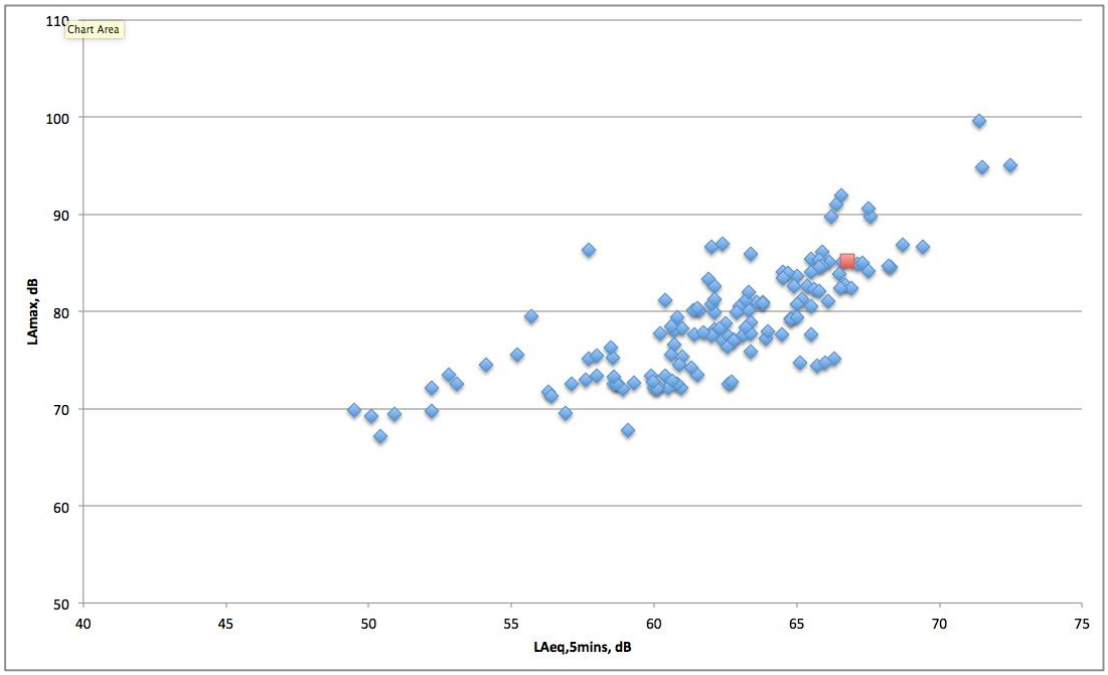


Figure 4-10 20 Allamanda Drive Noise Measurements

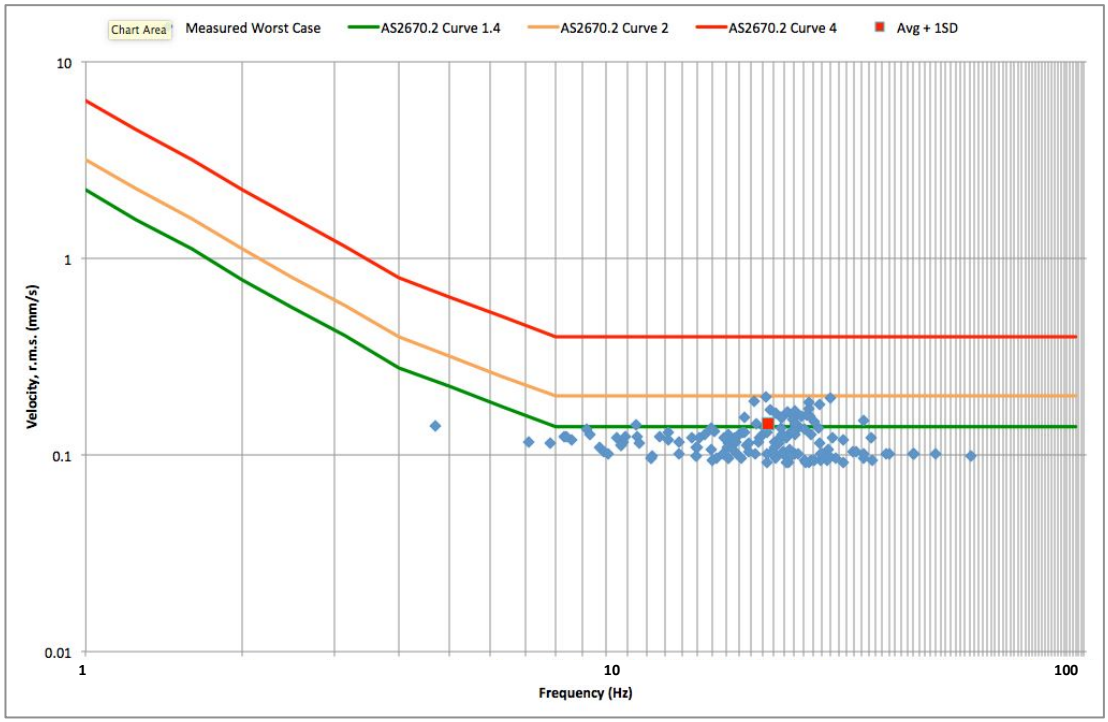


Figure 4-11 20 Allamanda Drive Vibration Measurements

4.6 12 Bullrush Drive

This location is central to the study area, on the north side of the track and in the second row. The results are summarised in *Figure 4-12* with only vibration monitoring undertaken. Note the red point is the average + 1 SD value for the data set.

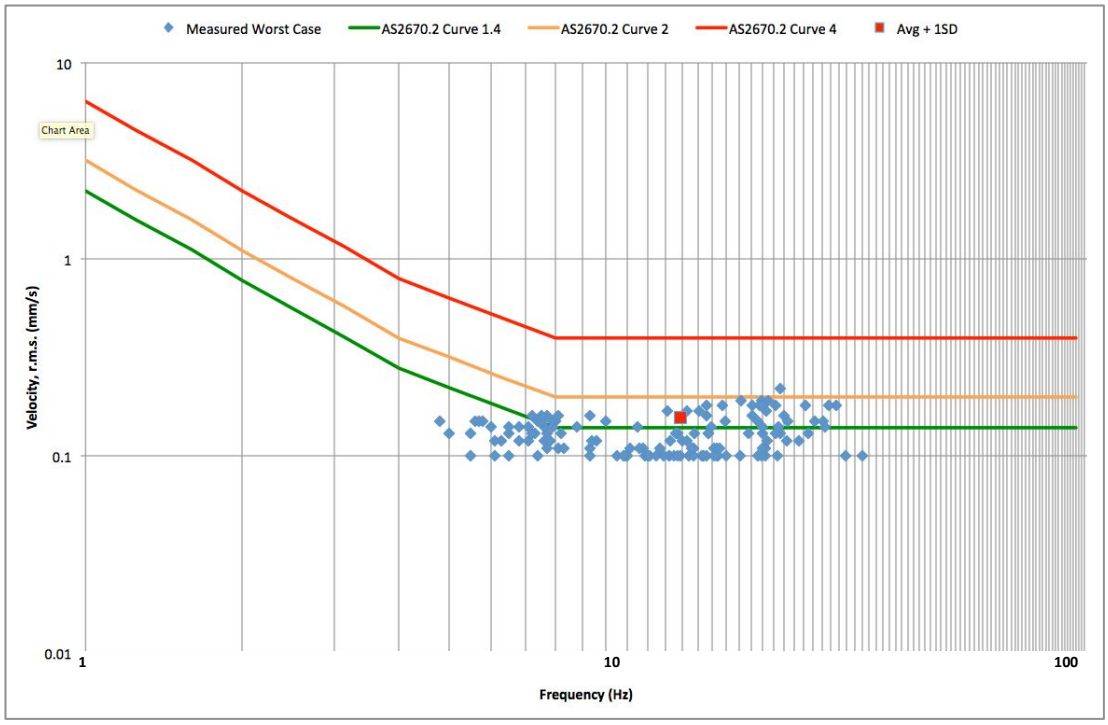


Figure 4-12 12 Bullrush Drive Vibration Measurements

4.7 37 Meller Drive

This location is central to the study area, on the north side of the track with the results summarised in *Figures 4-13 & 4-14*. Note the red point is the average + 1 SD value for the data set. Despite being 45 metres from the railway, vibration levels are relatively high at this location.

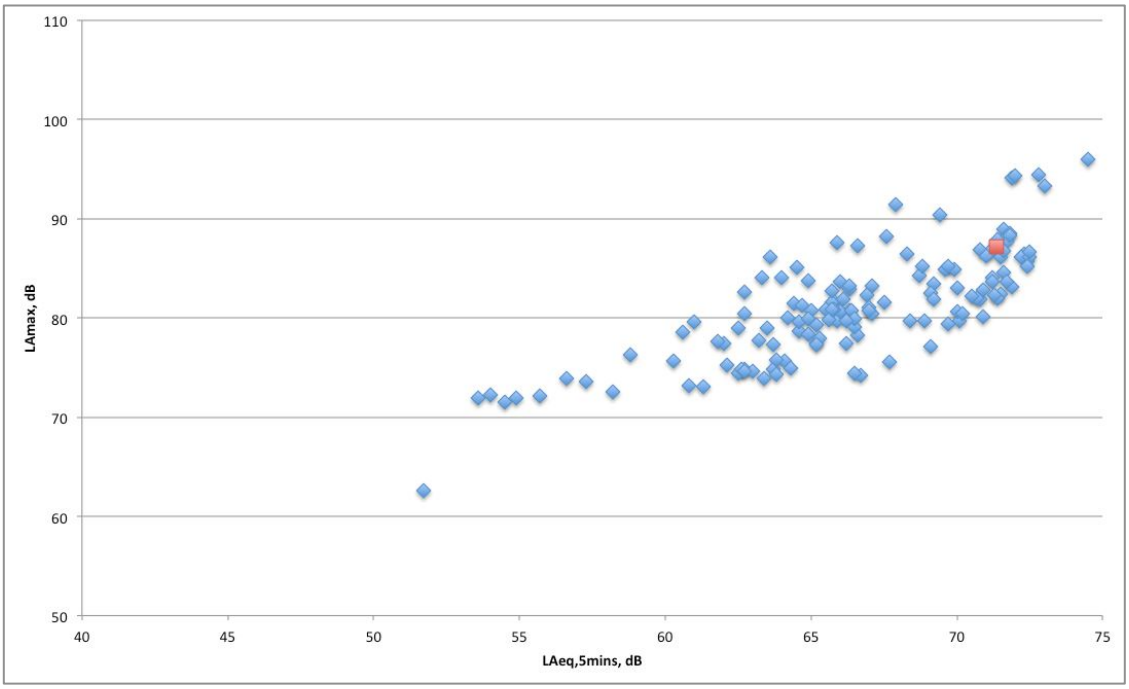


Figure 4-13 37 Meller Drive Noise Measurements

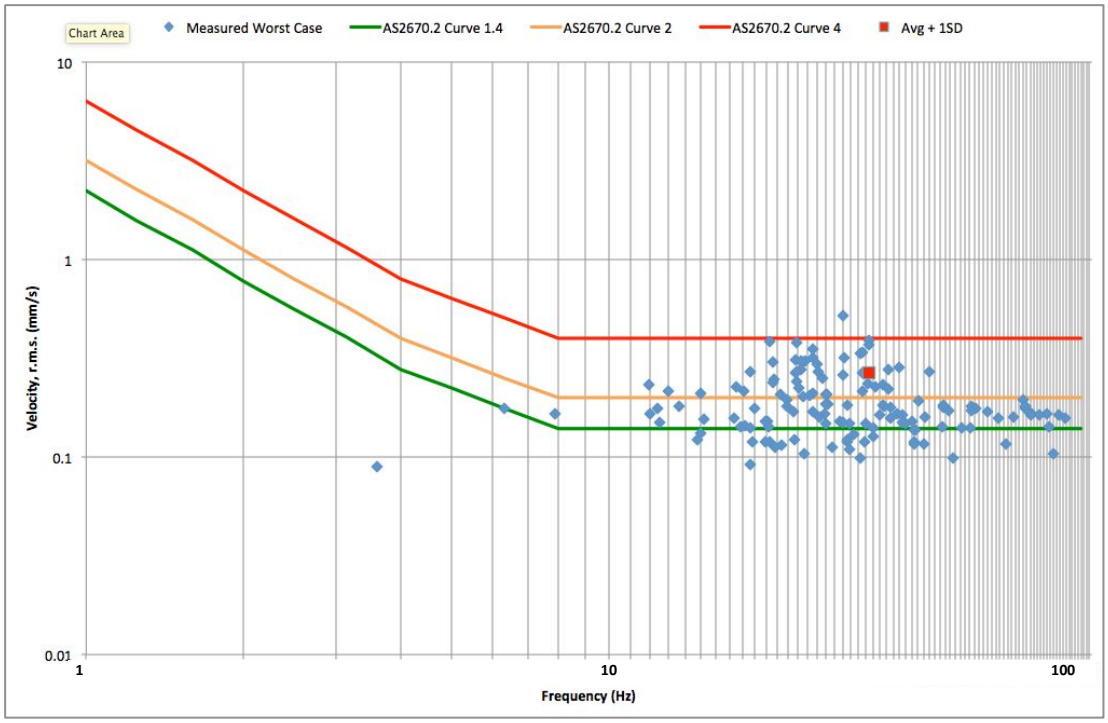


Figure 4-14 37 Meller Drive Vibration Measurements

4.8 10 Orchard Road

This location is central to the study area and on the south side of the track. The results are provided in *Figure 4-15*, being noise monitoring only. Note the red point is the average + 1 SD value for the data set.

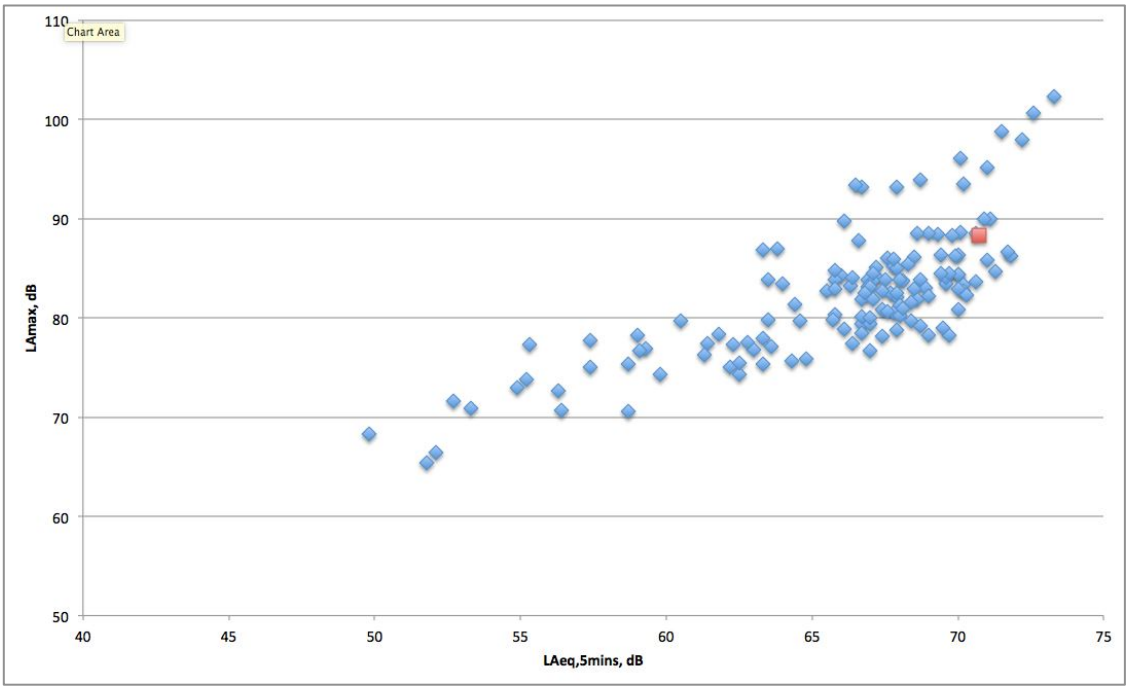


Figure 4-15 10 Orchard Road Noise Measurements

4.9 11 Citrus Loop

This location is towards the western end of the study area, on the south side of the track with the results summarised in *Figures 4-16 & 4-17*. Note the red point is the average + 1 SD value for the data set.

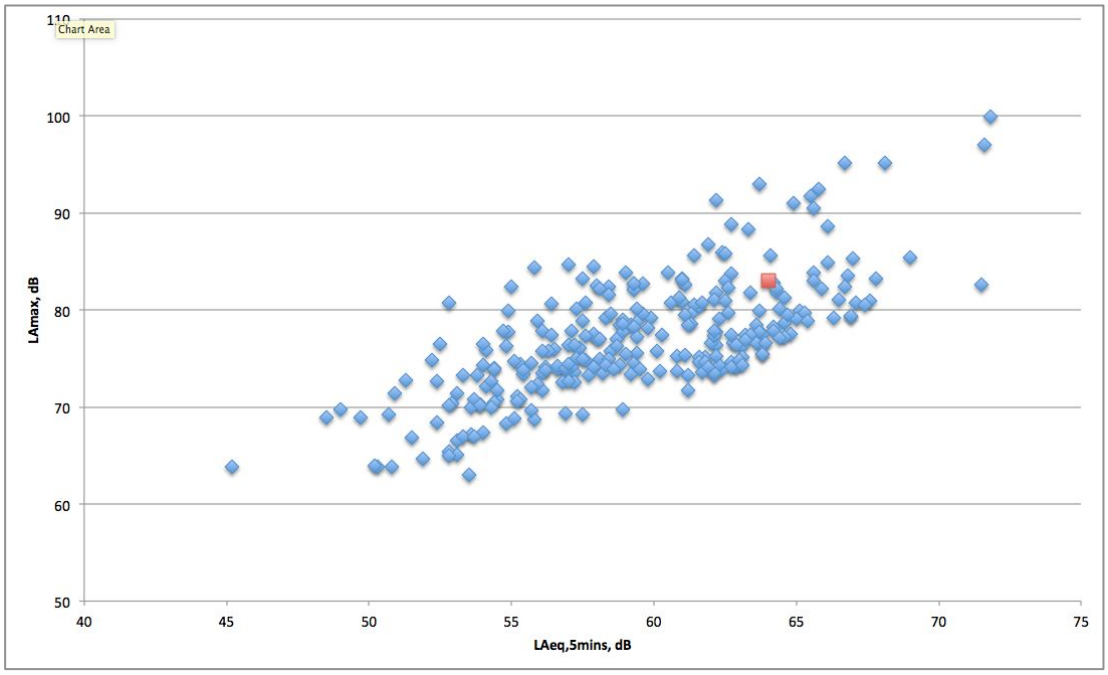


Figure 4-16 11 Citrus Loop Noise Measurements

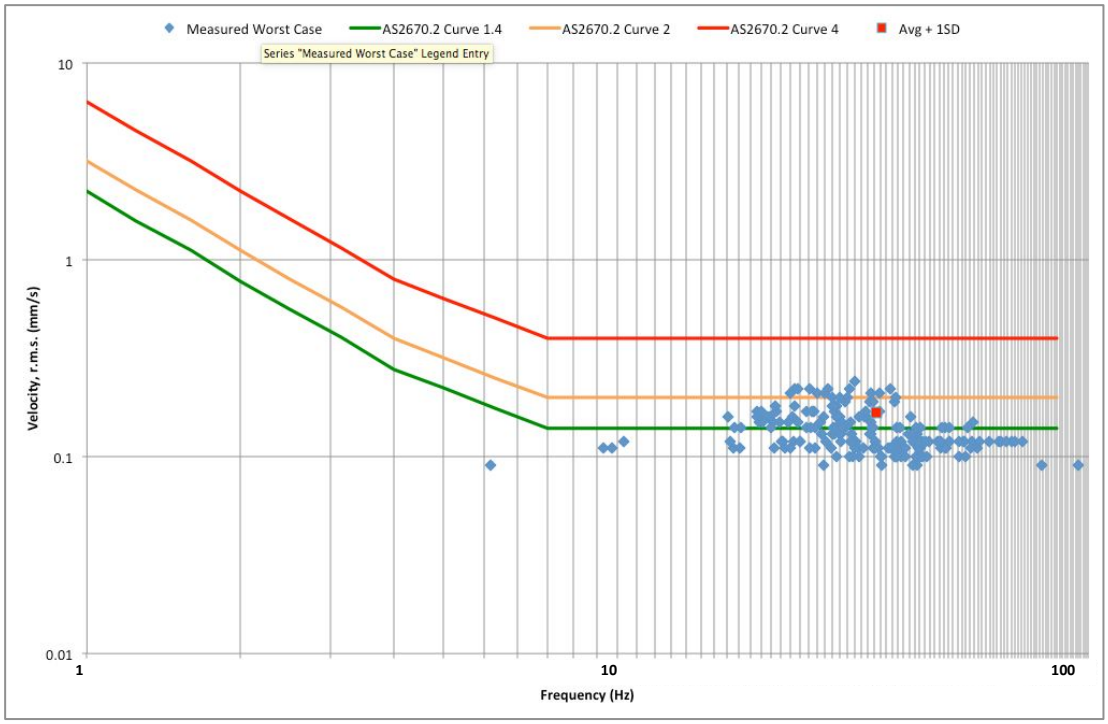


Figure 4-17 11 Citrus Loop Vibration Measurements

4.10 15 Meller Drive

This location is towards the western end of the study area, on the north side of the track with the results summarised in *Figures 4-18 & 4-19*. Note the red point is the average + 1 SD value for the data set.

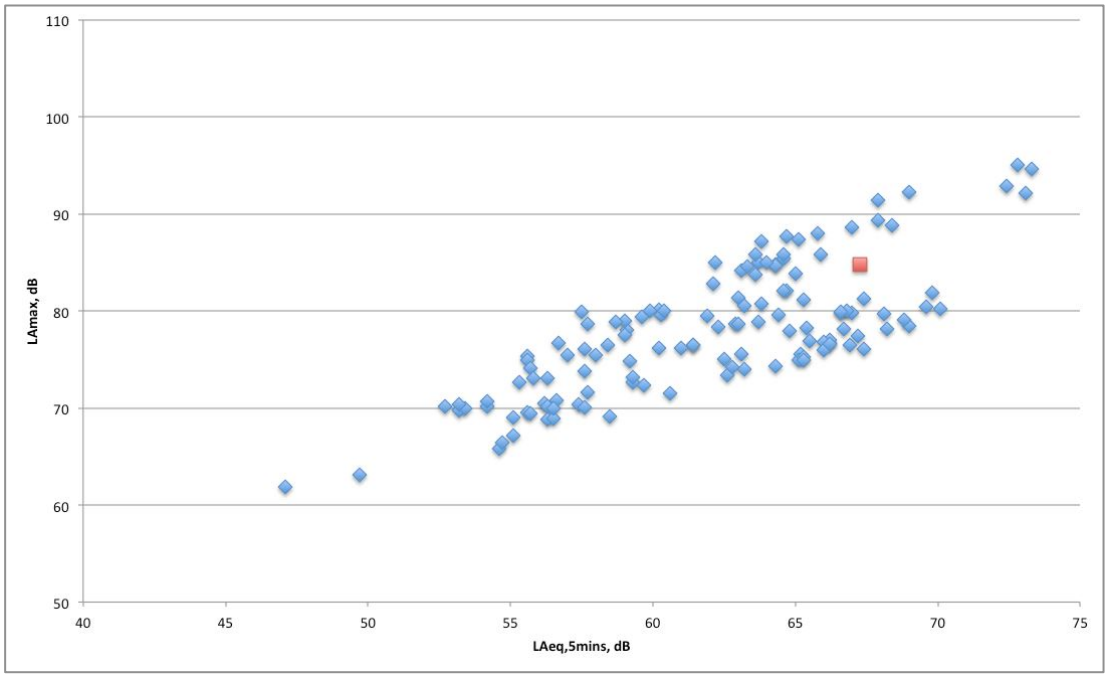


Figure 4-18 15 Meller Drive Noise Measurements

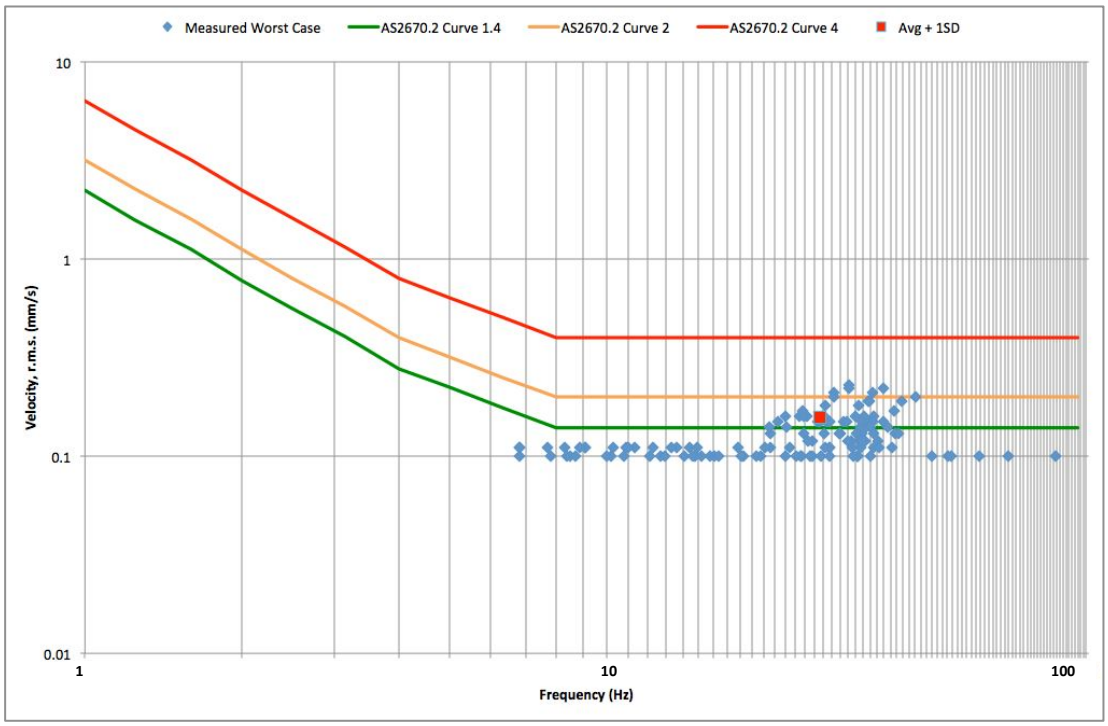


Figure 4-19 15 Meller Drive Vibration Measurements

4.11 2B Blackthorne Crescent

This is the western most location on the southern side of the track, with the results summarised in *Figures 4-20 & 4-21*. Note the red point is the average + 1 SD value for the data set.

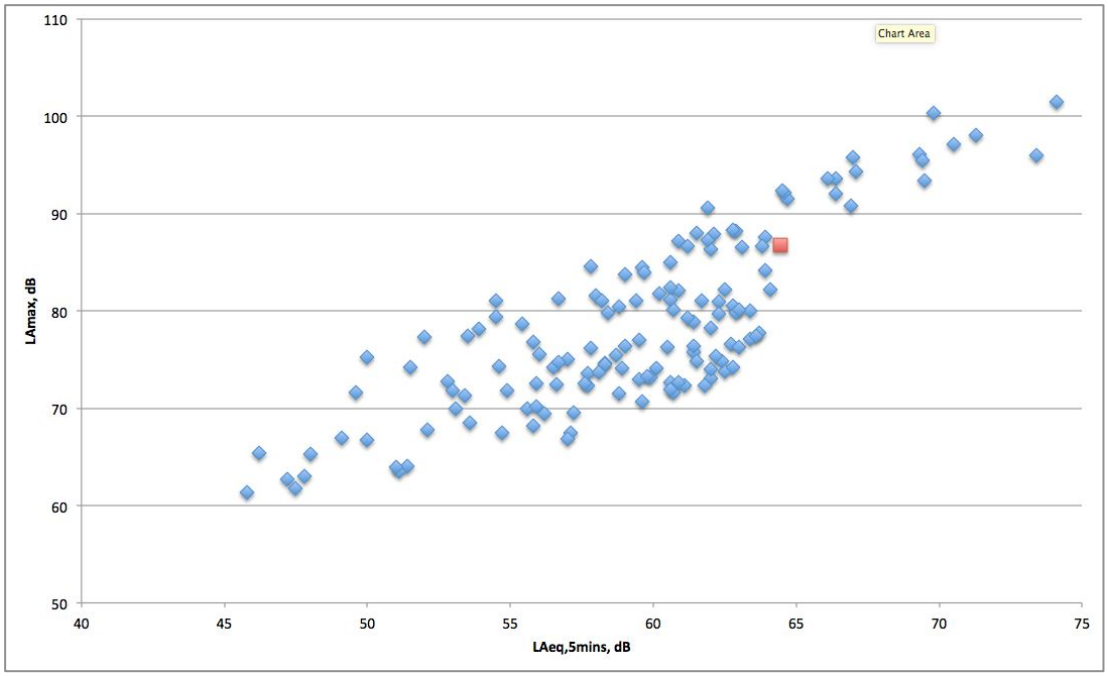


Figure 4-20 2B Blackthorne Crescent Noise Measurements

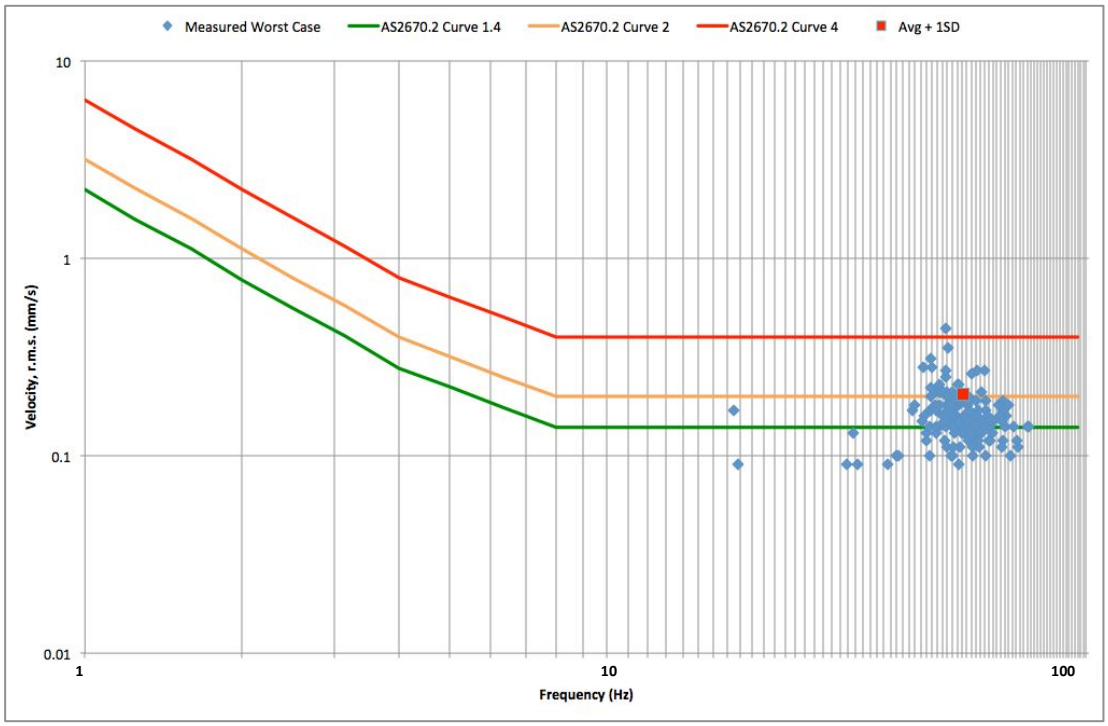


Figure 4-21 2B Blackthorne Crescent Vibration Measurements

4.12 1 Caphorn Close

This location is at the western end of the study area and on the north side of the track. The results are summarised in *Figures 4-22 to 4-24*, noting that noise was monitored at this location twice. Note the red point is the average + 1 SD value for the data set.

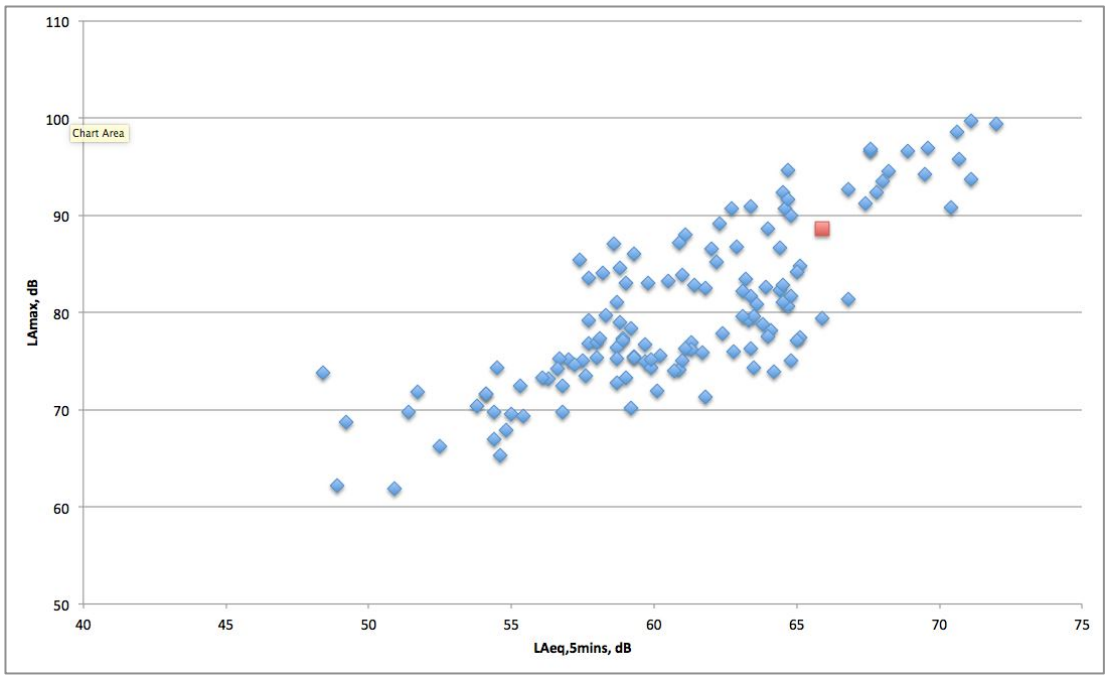


Figure 4-22 1 Caphorn Close Noise Measurements 1

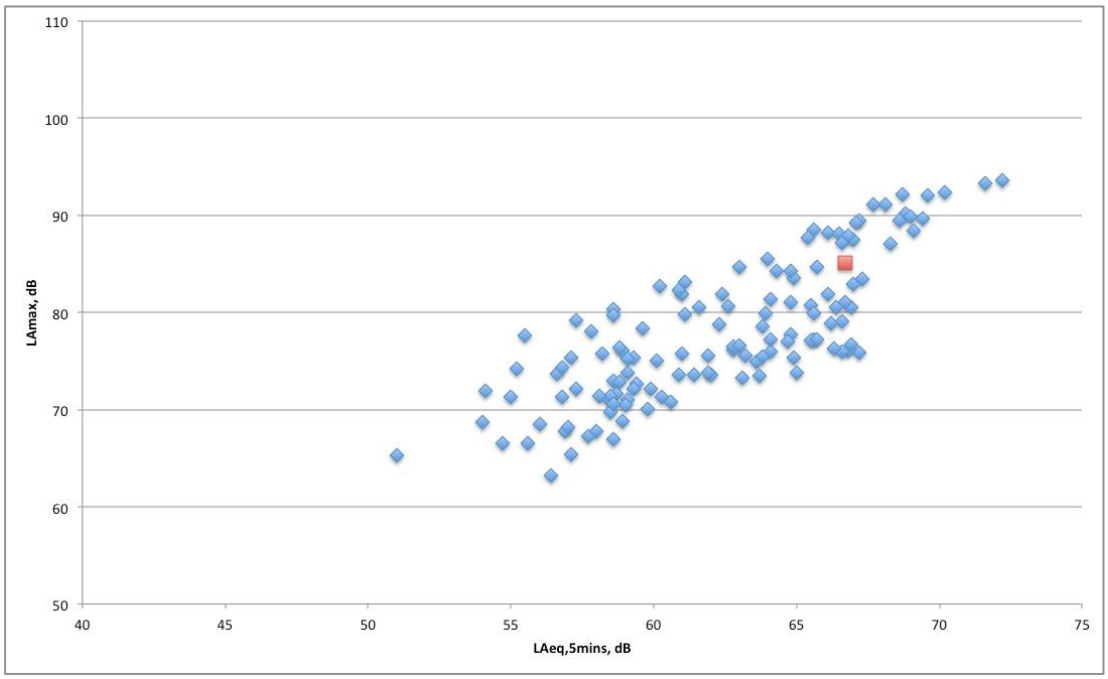


Figure 4-23 1 Caphorn Close Noise Measurements 2

Between the two measurement sets for the same locations, there is a 0.8 dB difference in the $L_{Aeq(Night)}$, which is relatively small, however there is a 3 dB difference in the L_{Amax}, which is reasonably significant. This demonstrates that even for the same location, there may be some differences between data sets.

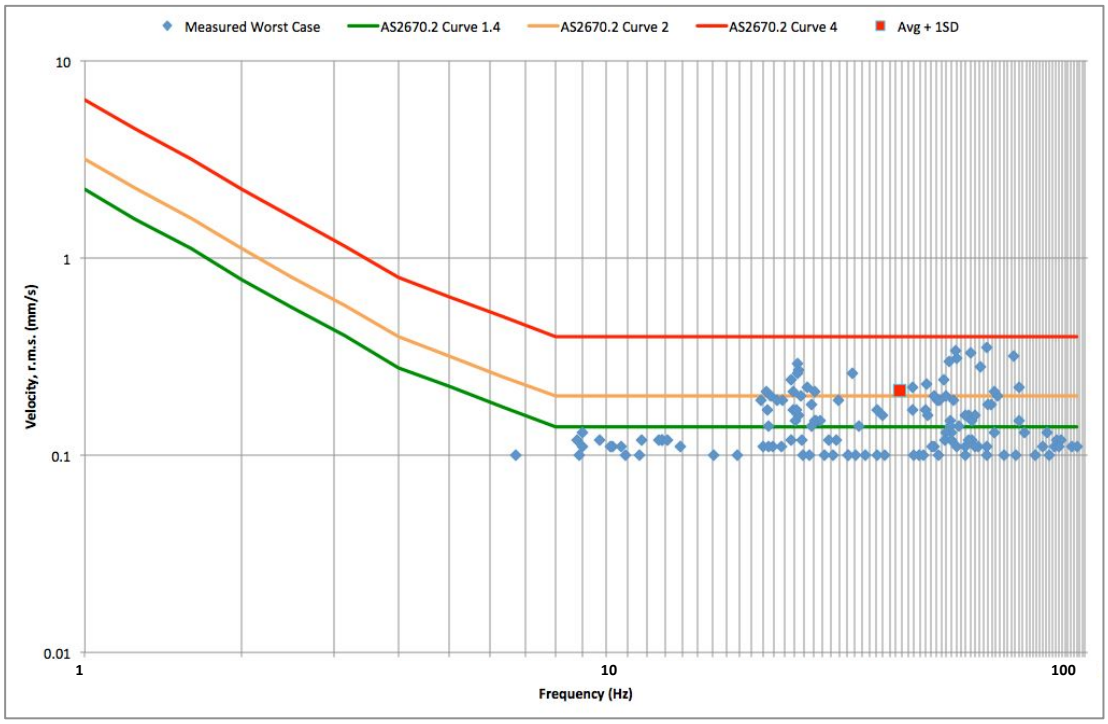


Figure 4-24 1 Caphorn Close Vibration Measurements

4.13 6 Ramsay Place

This is the western most location on the north side of the track, with the results summarised in *Figure 4-25*, noting that only noise measurements were undertaken here. Note the red point is the average + 1 SD value for the data set. Noise levels are the highest at this location due to the close proximity of the crossing, at which point trains sound their horns.

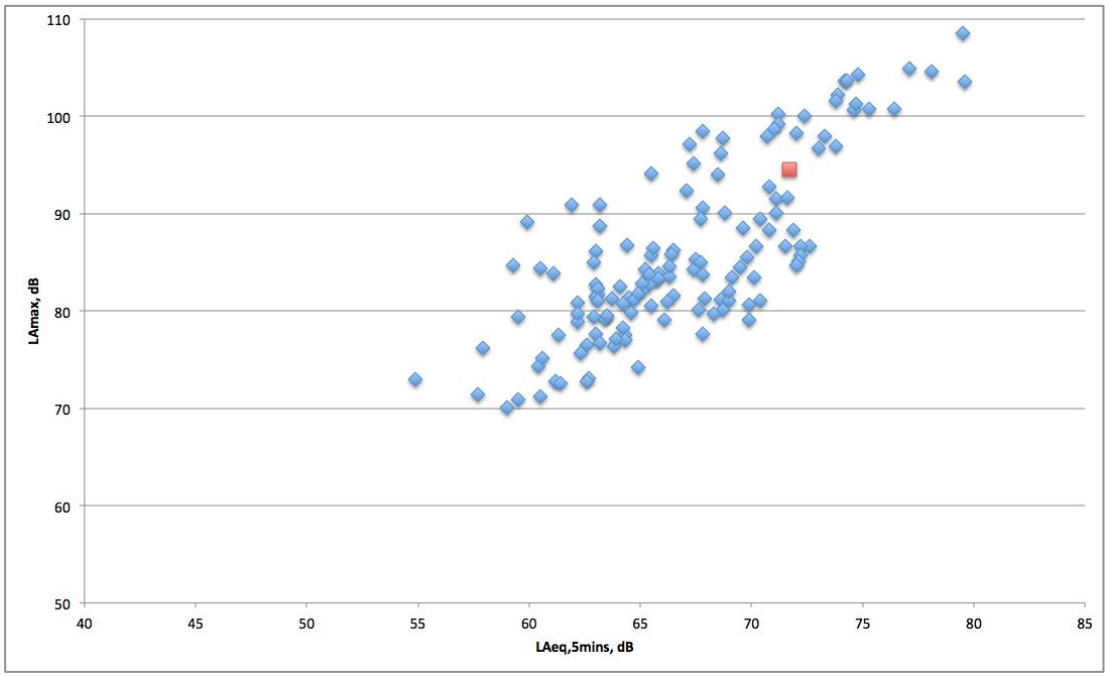


Figure 4-25 6 Ramsay Place Noise Measurements

5 NOISE MODELLING

Prior to producing noise contours, the model is to be calibrated. *Table 5-1* provides the accuracy of the final noise model, for both the $L_{Aeq(Night)}$ and L_{Amax} parameters.

Table 5-1 Noise Model Accuracy

Location	$L_{Aeq(Night)}$, dB			L_{Amax}, dB		
	Predicted	Measured	Difference	Predicted	Measured	Difference
15 Bloodwood Circle, South Lake	53.7	53.9	-0.2	85.8	85.8	0.0
1 Mudgee Court, South Lake	53.0	52.8	0.2	82.7	82.4	0.3
15A Sunshine Place, Bibra Lake	59.4	59.2	0.2	88.2	88.0	0.2
20 Allamanda Drive, South Lake	56.1	56.0	0.1	84.9	85.2	-0.3
37 Meller Road, Bibra Lake	61.0	60.6	0.4	88.8	87.1	1.7
10 Orchard Road, South Lake	60.4	59.9	0.5	87.7	88.3	-0.6
11 Citrus Loop, South Lake	54.4	53.2	1.2	83.4	83.0	0.4
15 Meller Road, Bibra Lake	56.6	56.5	0.1	85.4	84.8	0.6
2b Blackthorne Crescent, South Lake	53.9	53.7	0.2	86.4	86.7	-0.3
1 Caphorn Close, Bibra Lake	55.3	55.1	0.2	88.2	88.6	-0.4
1 Caphorn Close, Bibra Lake	55.3	55.9	-0.6	88.2	85.0	3.2
6 Ramsay Place, Bibra Lake	61.3	60.9	0.4	94.3	94.6	-0.3

It must be remembered that the noise model has been calibrated as far as practicable against the average + 1 SD values determined in *Section 4*. As such, there will be individual train noise events (around 10%) above those shown by the modelling.

Also, whilst the model has been calibrated to align very well with the measurements, there are significantly different corrections applied along the length of the track to achieve this result. This is not unexpected as parameters such as train speed, locomotive type, locomotive notch setting and the like have been fixed so that the calibration factor is essentially adjusting for this variation. Whilst these parameters are not known in detail, it is understood from the train operator that trains were operating normally and with no track restrictions during the monitoring sessions and are therefore considered representative.

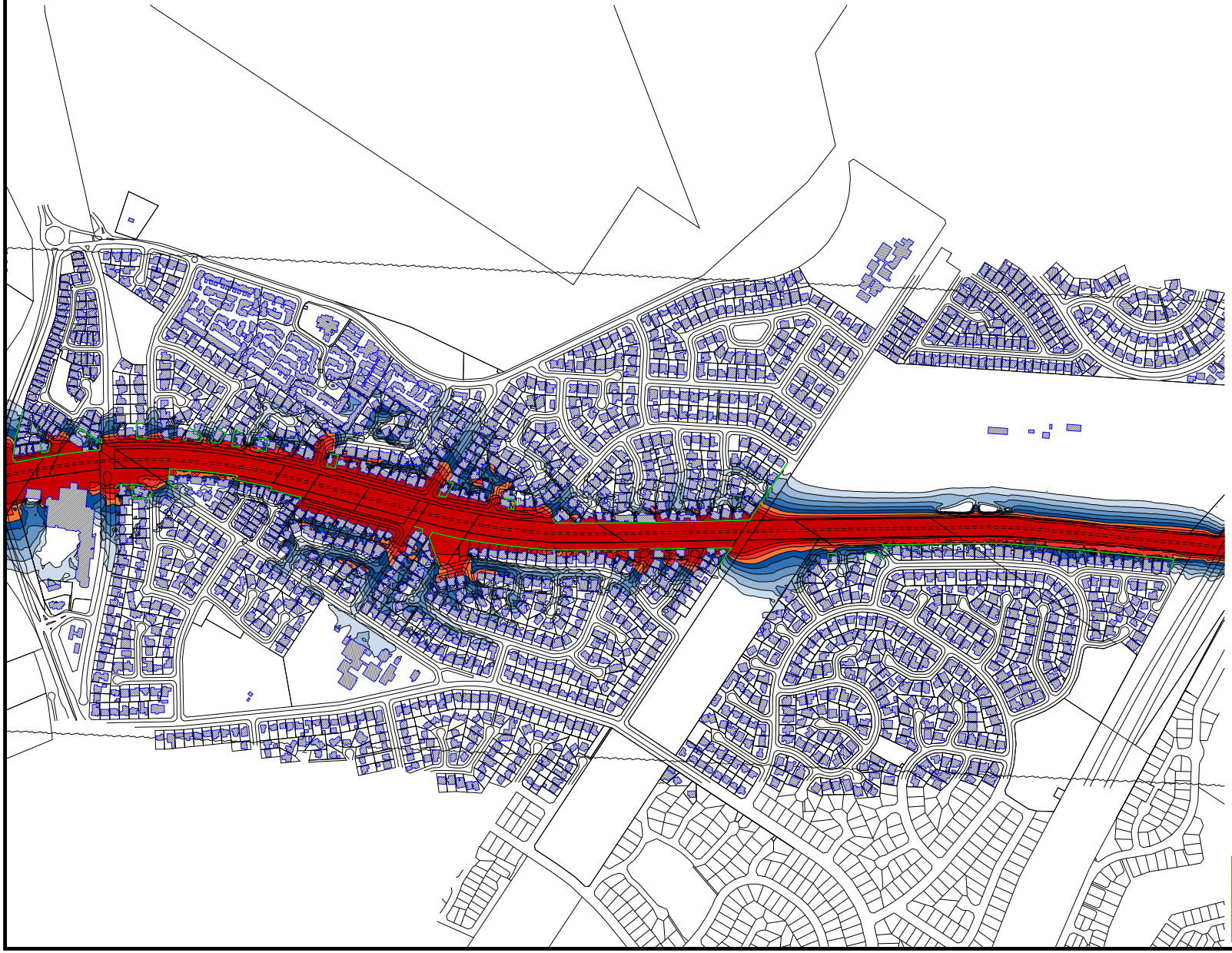
The results of the noise modelling are shown as noise contour plots in *Figures 5-1 to 5-8* as follows:

- *Figure 5-1* – $L_{Aeq(Night)}$ Noise Level Contours: Ground Floor
- *Figure 5-2* – L_{Amax} Noise Level Contours: Ground Floor
- *Figure 5-3* – $L_{Aeq(Night)}$ Noise Level Contours: First Floor
- *Figure 5-4* – L_{Amax} Noise Level Contours: First Floor
- *Figure 5-5* – $L_{Aeq(Night)}$ Noise Level Contours: Second Floor
- *Figure 5-6* – L_{Amax} Noise Level Contours: Second Floor
- *Figure 5-7* – $L_{Aeq(Night)}$ Noise Level Contours: Third Floor
- *Figure 5-8* – L_{Amax} Noise Level Contours: Third Floor

Figure 5-1

Cockburn Revitalisation - Freight Train Noise Impacts

LAeq(Night) Noise Level Contours: Ground Level



Noise levels
LAeq,night dB

	< 50
50 <=	< 51
51 <=	< 52
52 <=	< 53
53 <=	< 54
54 <=	< 55
55 <=	< 56
56 <=	< 57
57 <=	< 58
58 <=	

Signs and symbols

- Building
- Fence
- Railway

9 December 2016

Length Scale 1:12000

0 50 100 200 300 400 m

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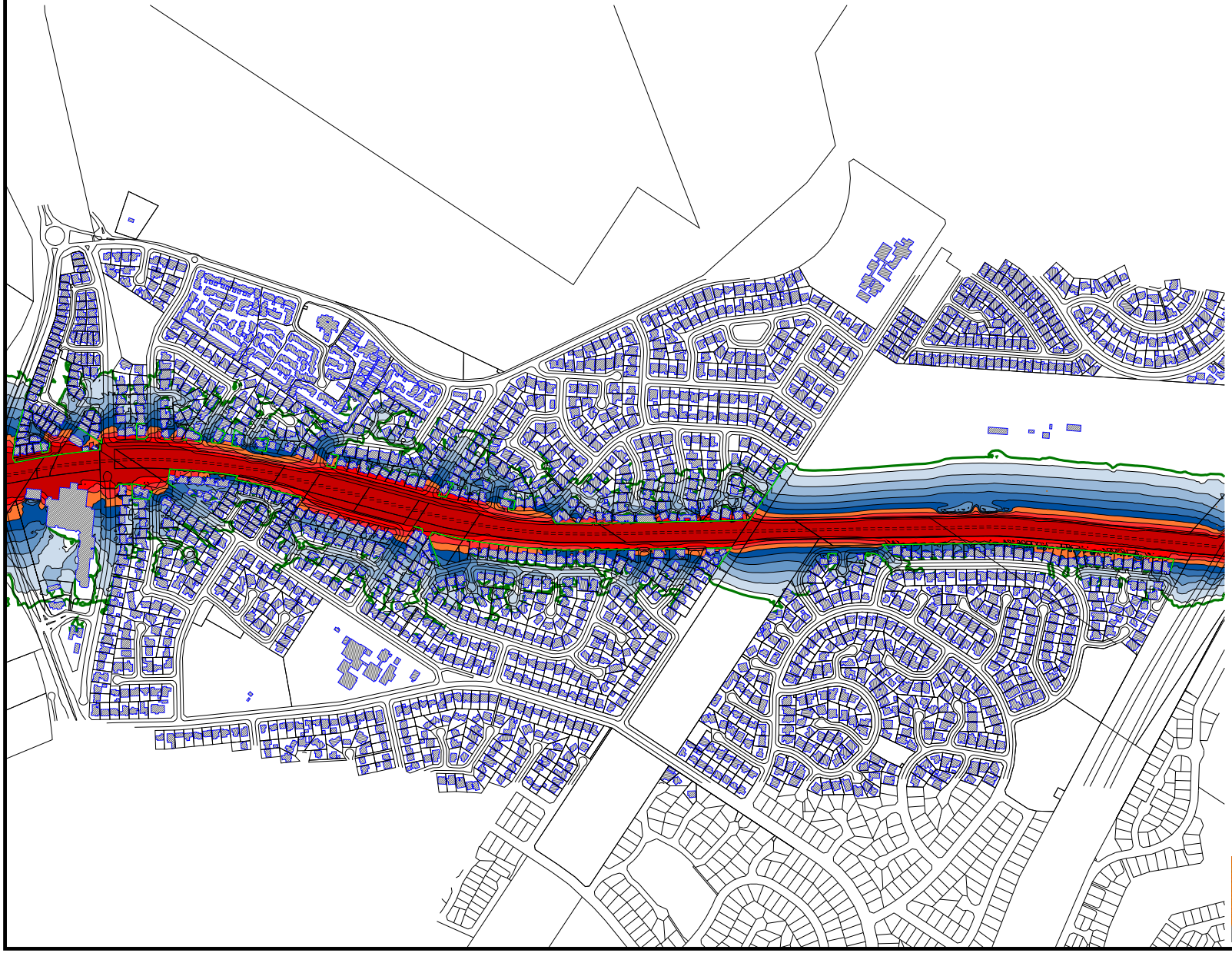
terry@lgacoustics.com.au
(08) 9401 7770

Cockburn Revitalisation - Freight Train Noise Impacts

LAmax Noise Level Contours: Ground Level

Figure 5-2



Noise levels
LAmax dB

	< 76
76 <=	< 78
78 <=	< 80
80 <=	< 82
82 <=	< 84
84 <=	< 86
86 <=	< 88
88 <=	< 90
90 <=	< 92
92 <=	

N

Signs and symbols

- Building
- Fence
- Railway

11 December 2016

Length Scale 1:12000

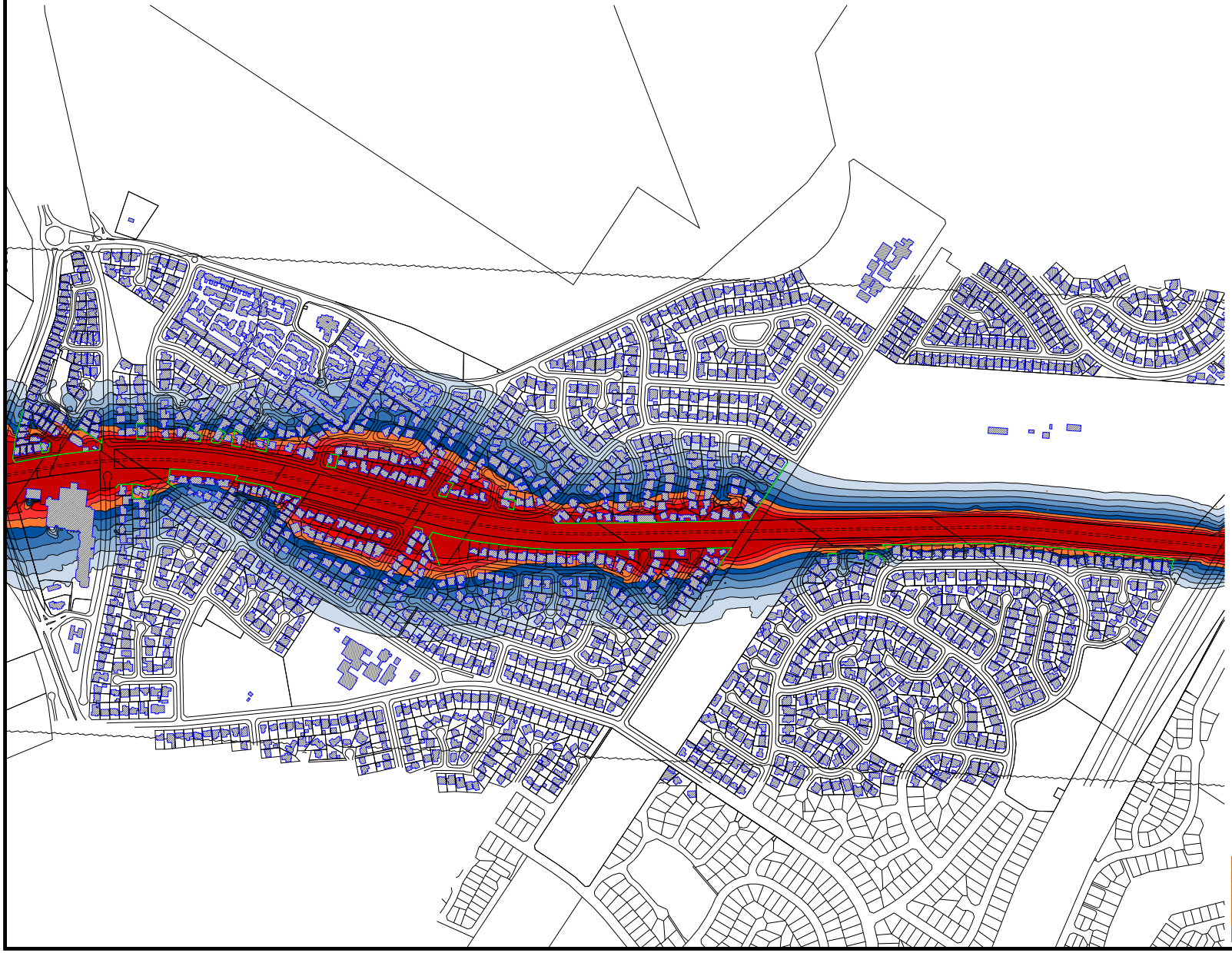
0 50 100 200 300 400 m

Lloyd George Acoustics
by Terry George
terry@lgacoustics.com.au
(08) 9401 7770

Figure 5-3

Cockburn Revitalisation - Freight Train Noise Impacts

LAeq(Night) Noise Level Contours: First Level



Noise levels
LAeq,night dB

	< 50
50 <=	< 51
51 <=	< 52
52 <=	< 53
53 <=	< 54
54 <=	< 55
55 <=	< 56
56 <=	< 57
57 <=	< 58
58 <=	

Signs and symbols

- Building
- Fence
- Railway

10 December 2016

Length Scale 1:12000

0 50 100 200 300 400 m

Lloyd George Acoustics
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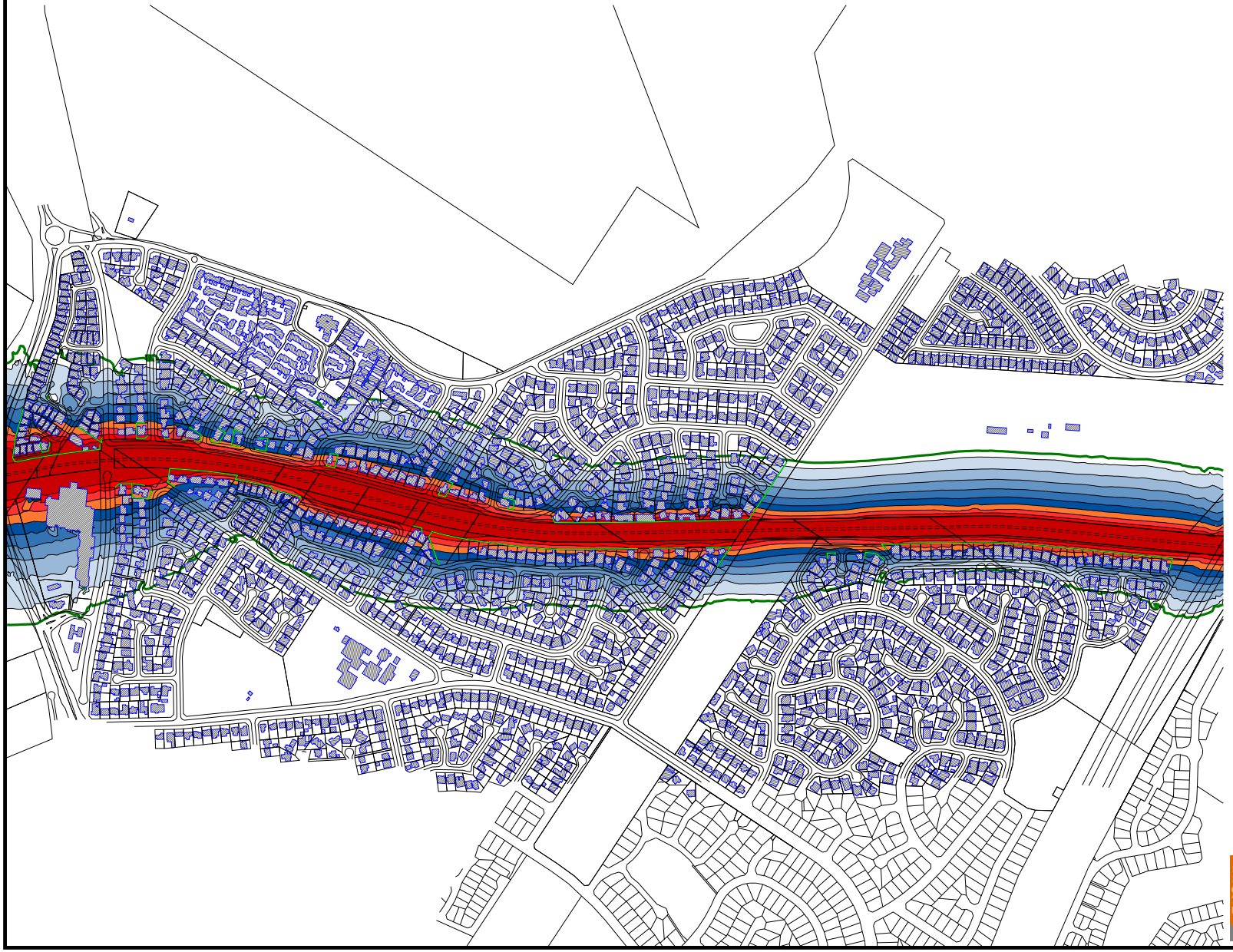
terry@lgacoustics.com.au
(08) 9401 7770

Figure 5-4

Cockburn Revitalisation - Freight Train Noise Impacts

LAmax Noise Level Contours: First Level



Noise levels
LAmax dB

	< 76
76 <=	< 78
78 <=	< 80
80 <=	< 82
82 <=	< 84
84 <=	< 86
86 <=	< 88
88 <=	< 90
90 <=	< 92
92 <=	

N

Signs and symbols

- Building
- Fence
- Railway

11 December 2016

Length Scale 1:12000

0 50 100 200 300 400 m

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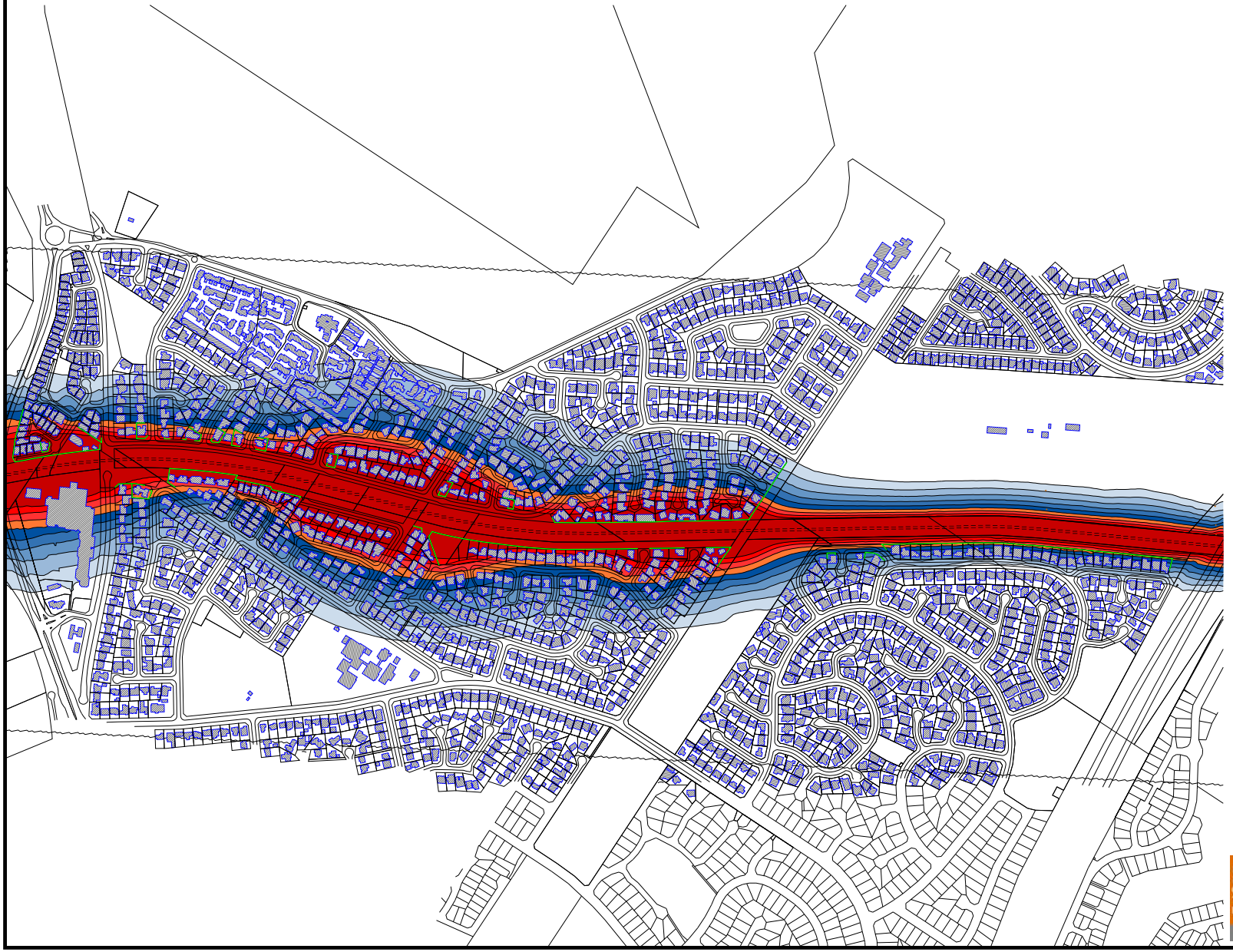
Cockburn Revitalisation - Freight Train Noise Impacts

LAeq(Night) Noise Level Contours: Second Level

Figure 5-5



Noise levels
LAeq,night dB

50 <=	< 51
51 <=	< 52
52 <=	< 53
53 <=	< 54
54 <=	< 55
55 <=	< 56
56 <=	< 57
57 <=	< 58
58 <=	

Signs and symbols

- Building
- Fence
- Railway

11 December 2016

Length Scale 1:12000

0 50 100 200 300 400 m

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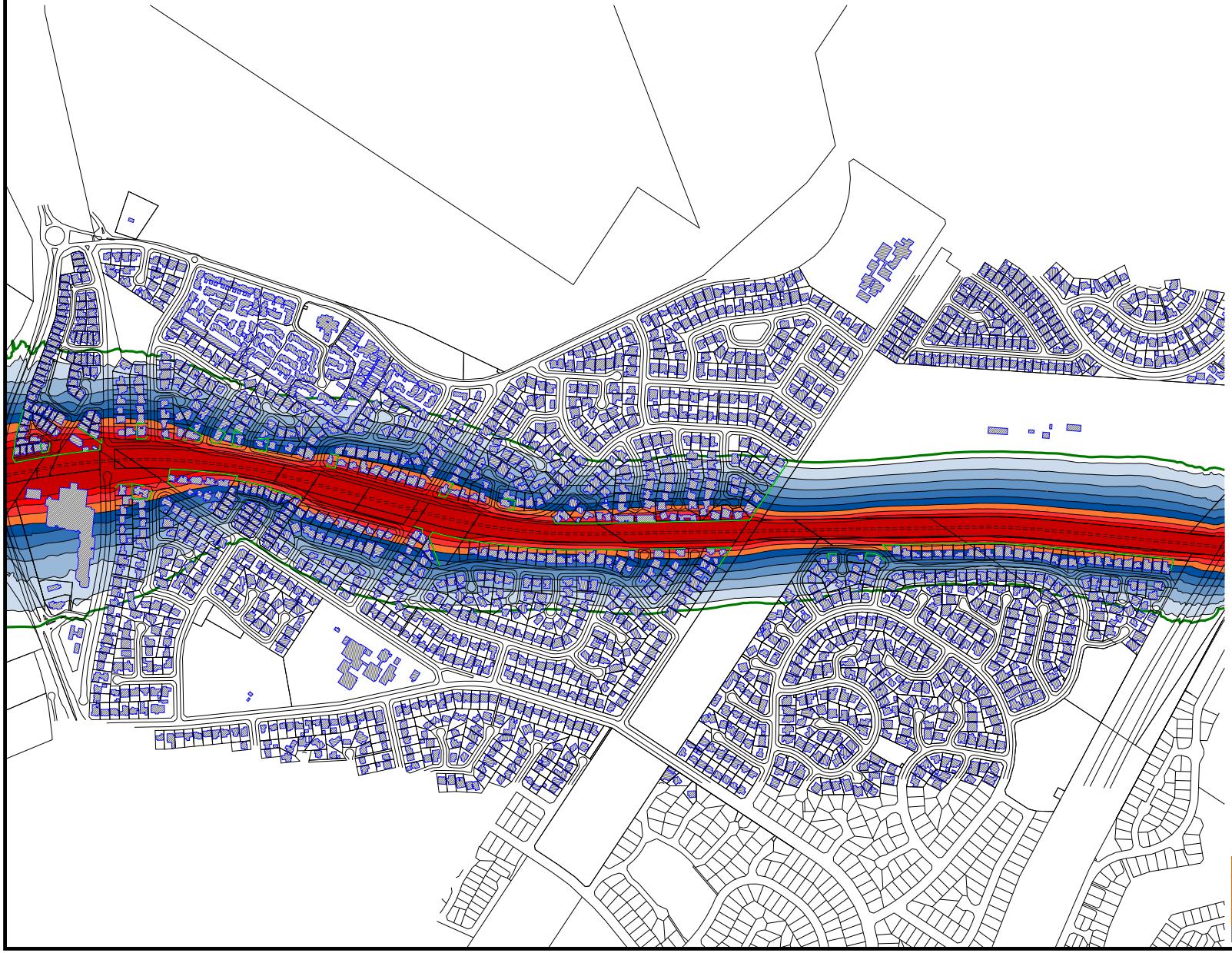
(08) 9401 7770

Cockburn Revitalisation - Freight Train Noise Impacts

LAmax Noise Level Contours: Second Level

Figure 5-6



Noise levels
LAmax dB

	< 76
76 <=	< 78
78 <=	< 80
80 <=	< 82
82 <=	< 84
84 <=	< 86
86 <=	< 88
88 <=	< 90
90 <=	< 92
92 <=	

Signs and symbols

- Building
- Fence
- Railway

11 December 2016

Length Scale 1:12000

0 50 100 200 300 400 m

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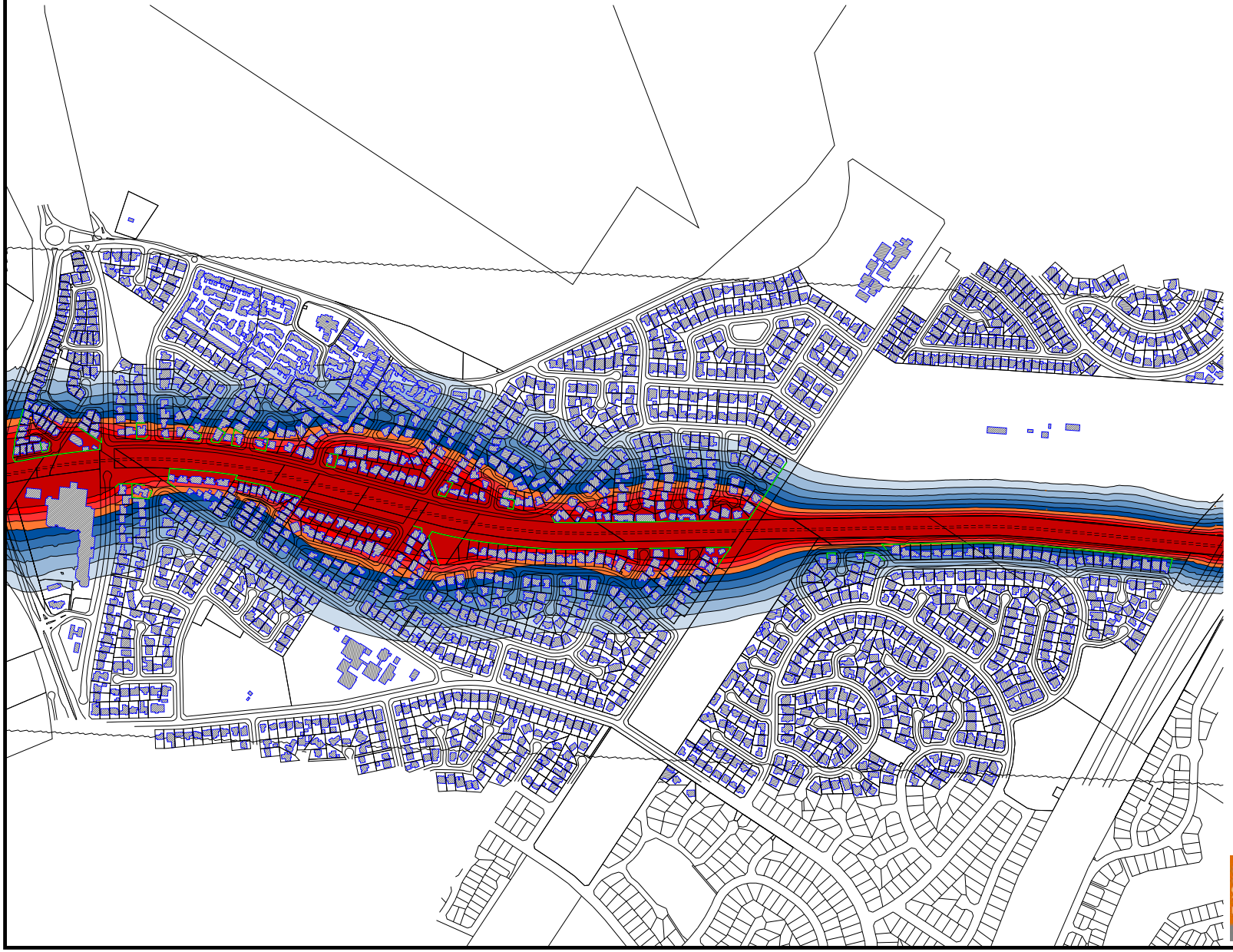
Cockburn Revitalisation - Freight Train Noise Impacts

LAeq(Night) Noise Level Contours: Third Level

Figure 5-7



Noise levels
LAeq,night dB

	< 50
50 <=	< 51
51 <=	< 52
52 <=	< 53
53 <=	< 54
54 <=	< 55
55 <=	< 56
56 <=	< 57
57 <=	< 58
58 <=	

Signs and symbols

- Building
- Fence
- Railway

11 December 2016

Length Scale 1:12000

0 50 100 200 300 400 m

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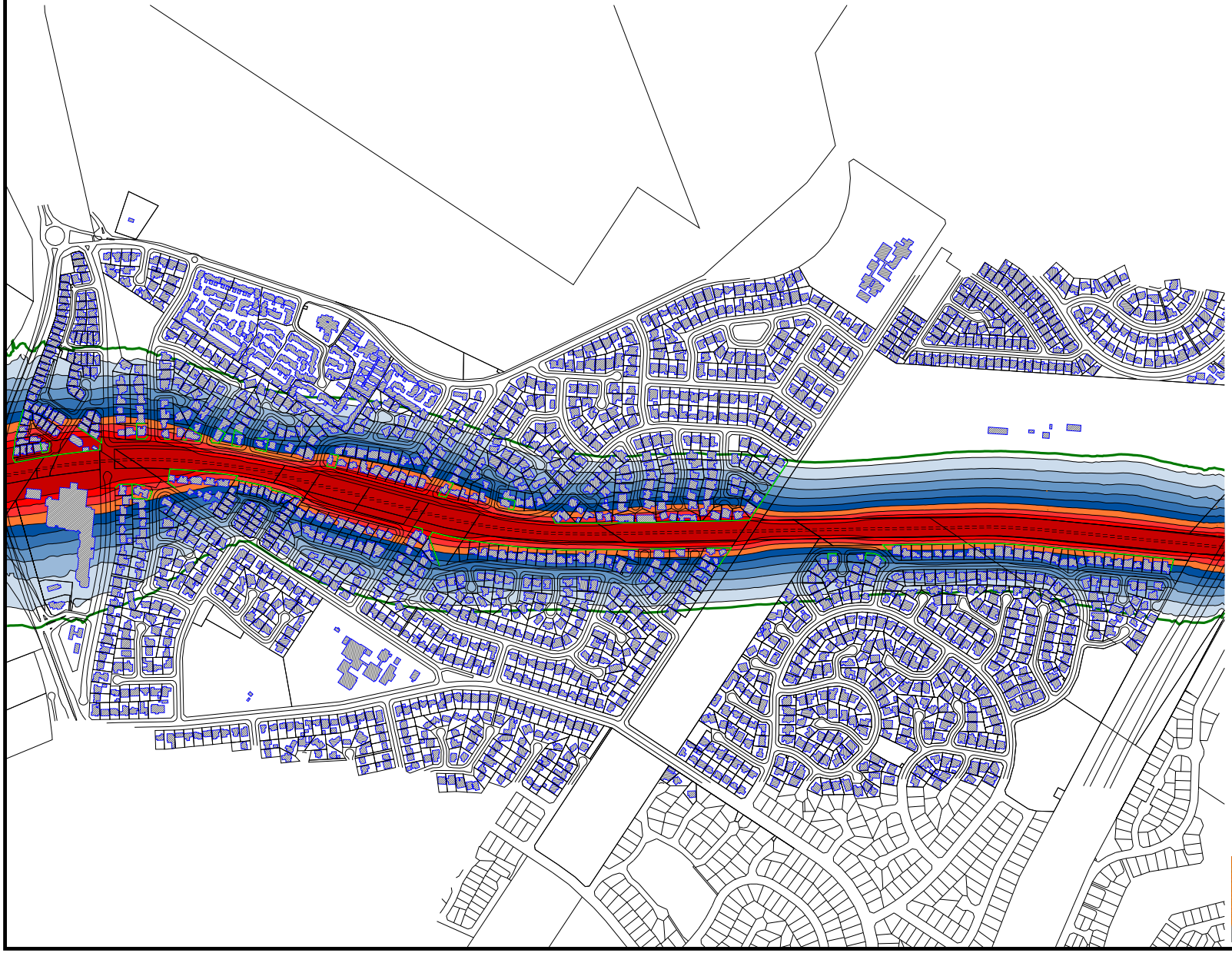
Figure 5-8

Cockburn Revitalisation - Freight Train Noise Impacts

LAmax Noise Level Contours: Second Level



Noise levels
LAmax dB

	< 76
76 <=	< 78
78 <=	< 80
80 <=	< 82
82 <=	< 84
84 <=	< 86
86 <=	< 88
88 <=	< 90
90 <=	< 92
92 <=	

Signs and symbols

- Building
- Fence
- Railway

11 December 2016

Length Scale 1:12000

0 50 100 200 300 400 m

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6 VIBRATION ANALYSIS

The results of the vibration analysis are provided in *Figures 6-1 & 6-2*, noting the following:

- No locations were deemed to have vibration levels above Curve 3, with the worst-case result being Curve 2.8. This should be viewed with some caution as this value is the average + 1SD as discussed earlier. *Table 6-1* shows the percentage of trains at each location above Curve 2, 3 & 4.

Table 6-1 Further Vibration Analysis

Location	Assessed AS2670.2 Curve (Avg + 1SD)	% Above Curve 2	% Above Curve 3	% Above Curve 4
15 Bloodwood Circle, South Lake	1.3	0.0	0.0	0.0
15A Sunshine Place, Bibra Lake	2.8	44.7	11.4	3.3
17 Allamanda Drive, South Lake	1.8	8.5	0.0	0.0
20 Allamanda Drive, South Lake	1.4	0.0	0.0	0.0
12 Bullrush Drive, Bibra Lake	1.6	0.7	0.0	0.0
37 Meller Road, Bibra Lake	2.7	33.8	10.8	0.7
11 Citrus Loop, South Lake	1.7	7.1	0.0	0.0
15 Meller Road, Bibra Lake	1.6	5.2	0.0	0.0
2b Blackthorne Crescent, South Lake	2.1	15.5	1.5	0.5
1 Caphorn Close, Bibra Lake	2.1	20.0	4.6	0.0

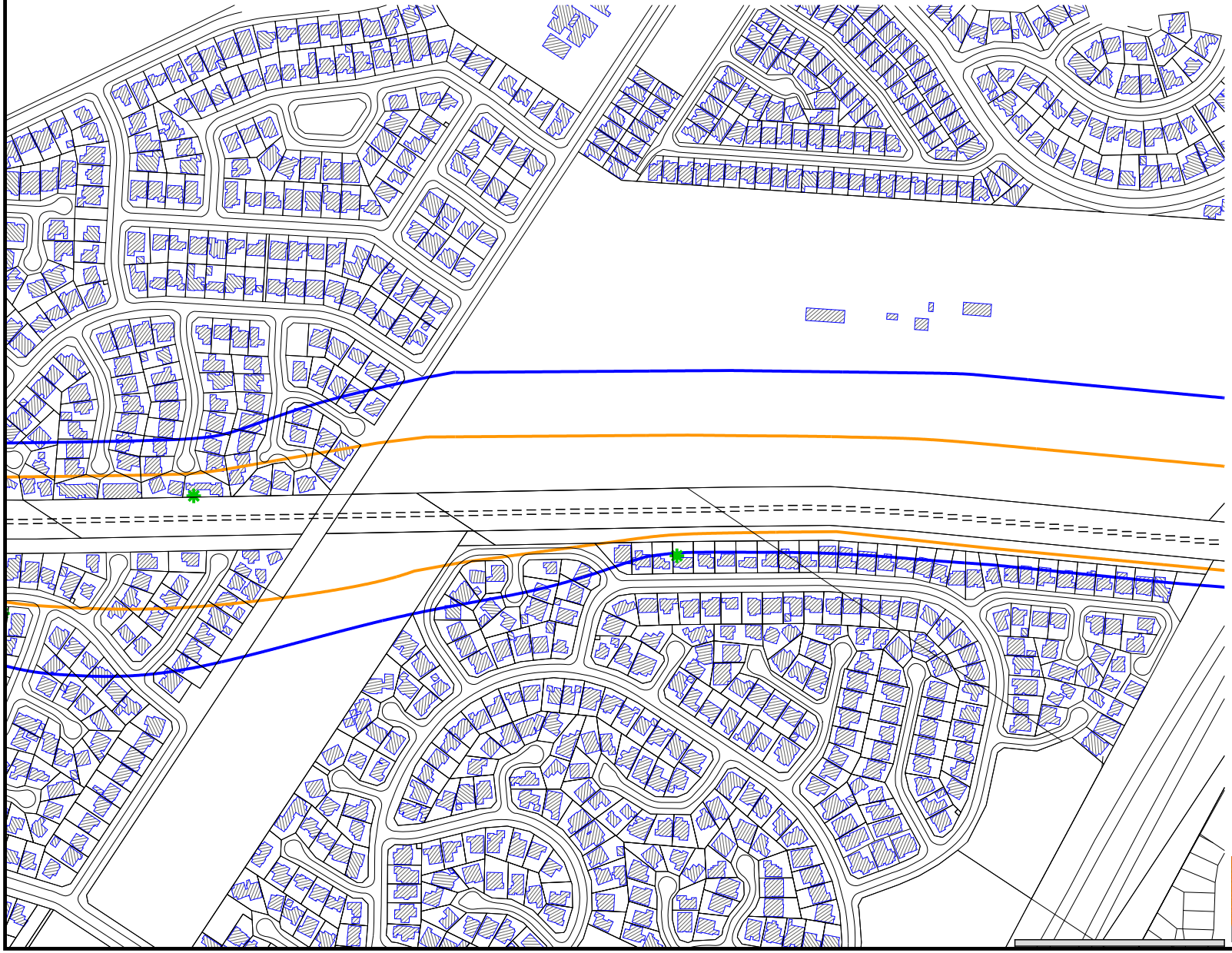
Note: % Above Curve 2 includes Curve 3 and Curve 4 trains and similarly, % Above Curve 3 includes Curve 4 trains.

- Vibration levels were relatively low at 15 Bloodwood Circle. This could be related to the topography as the rail is in a significant cutting at this point.
- Vibration levels at 17 Allamanada Drive were higher than those at 20 Allamanda Drive, with the latter residence being closer to the rail. As such, the 17 Allamanda results were used in the analysis to be conservative.
- Vibration levels at 15a Sunshine Place were the highest, which is expected given this is the closest to the track.
- Vibration levels at 37 Meller Road were relatively high, given it is similar in level to 15a Sunshine but twice as far away.
- A relationship of vibration levels reducing at a rate of 1.5 per doubling of distance has been found as reasonable in the past and was used to supplement the measurements.
- The final zones for vibration are to be rationalised (e.g. all first row houses to be assumed as being above Curve 2 etc).

Figure 6-1

Cockburn Revitalisation - Freight Train Noise & Vibration Impacts

Buffer Distances: Vibration Part 1



Signs and symbols

- Building
- Railway
- Curve 2
- Curve 1.4
- Monitoring Location

8 December 2016

Length Scale 1:6000

0 30 60 120 180 240 m

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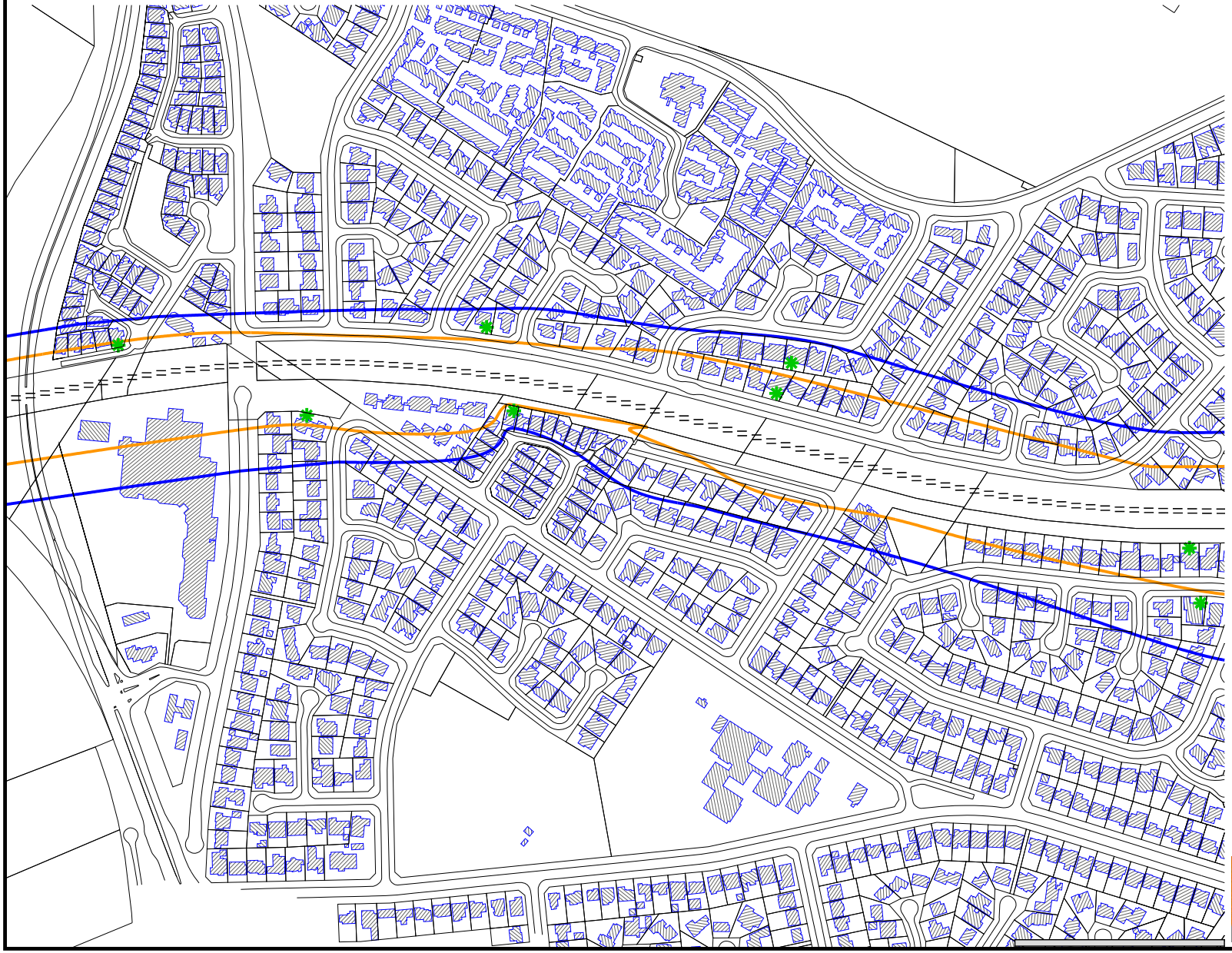
Cockburn Revitalisation - Freight Train Noise & Vibration Impacts

Buffer Distances: Vibration Part 2

Figure 6-2



Signs and symbols

- Building
- Railway
- Curve 2
- Curve 1.4
- Monitoring Location

8 December 2016

Length Scale 1:6000

0 30 60 120 180 240 m

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7 NOISE & VIBRATION BUFFERS

The outcome of the Study is a series of buffers or zones, at which different requirements would be applicable. These requirements will vary depending on whether or not the development is single or multiple storey, as permitted under the new density codes. The requirements are summarised in *Table 5-1* with *Figures 7-1 to 7-4* identifying affected lots.

Table 7-1 Buffer Zone and Requirements for New Developments

Buffer Zone	Requirements
Vibration	
Above Curve 2	Vibration isolation to be incorporated to reduce levels to below Curve 1.4 within dwelling – specialist advice to be sought. Notification on title mandatory with regards to vibration. Site specific measurements (in accordance with methodology of this report) can be undertaken by a suitably qualified consultant in order to deviate from this requirement.
Curve 1.4 to Curve 2	No mandatory vibration isolation requirements. Notification on title with regards to vibration required.
Outside Curve 1.4	No vibration requirements
Noise	
L_{Amax} > 92 dB	Specialist advice to be sought from suitably qualified acoustical consultant being a member firm of the AAAC*. Notification on title mandatory with regards to noise. Site specific measurements (in accordance with methodology of this report) mandatory.
88 > L_{Amax} ≥ 92 dB	Implement Package CF or alternative construction supported by report from suitably qualified acoustical consultant being a member firm of the AAAC*. Notification on title mandatory with regards to noise.
80 > L_{Amax} ≥ 88 dB	Implement Package BF or alternative construction supported by report from suitably qualified acoustical consultant being a member firm of the AAAC*. Notification on title mandatory with regards to noise.
$L_{Aeq(Night)}$ > 50 or L_{Amax} 75 dB & L_{Amax} < 80 dB	Implement Package AF or alternative construction supported by report from suitably qualified acoustical consultant being a member firm of the AAAC*. Notification on title mandatory with regards to noise.

* Association of Australian Acoustical Consultants.

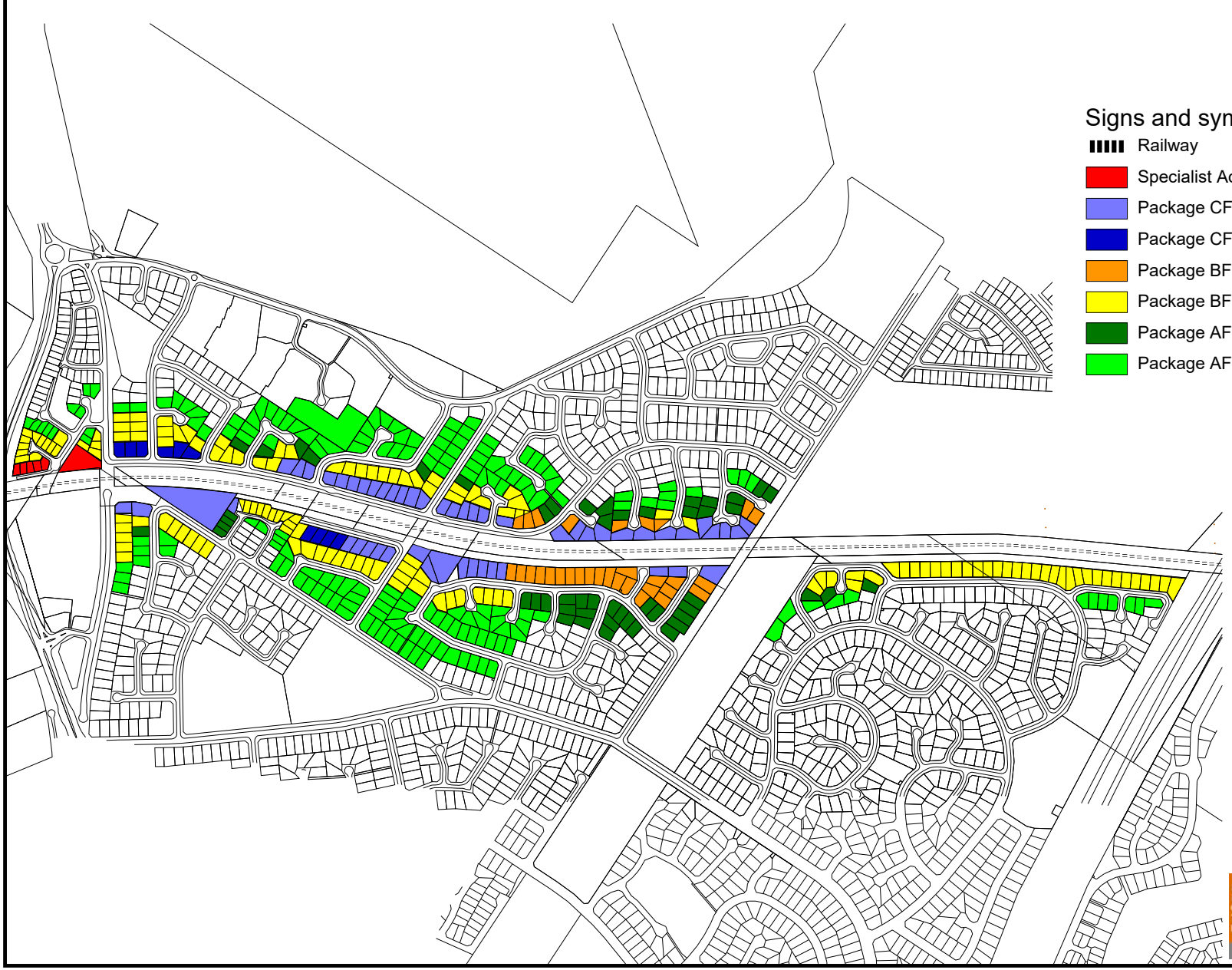
Notification on title is to read:

This lot or dwelling is in the vicinity of an operating freight rail line servicing the Ports of Fremantle and Kwinana as well as industrial areas and operates 24 hours a day, 7 days a week. Residential amenity may be affected by noise and vibration and other impacts from freight rail traffic using the rail line.

Cockburn Revitalisation - Freight Train Noise & Vibration Impacts

Default Packages: Ground Level

Figure 7-1



Signs and symbols

- Railway
- Specialist Advice, Vibe Attenuation & Notification
- Package CF, Vibe Attenuation & Notification
- Package CF & Notification
- Package BF, Vibe Attenuation & Notfication
- Package BF & Notification
- Package AF & Notification
- Package AF & Notification

12 January 2017

Length Scale 1:12000

0 50 100 200 300 400 m

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Cockburn Revitalisation - Freight Train Noise Impacts

Default Packages: First Level

Figure 7-2

Signs and symbols

- Railway
- Specialist Advice
- Package CF
- Package BF
- Package AF

12 December 2016

Length Scale 1:12000

0 50 100 200 300 400 m

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Cockburn Revitalisation - Freight Train Noise Impacts

Default Packages: Second Level

Figure 7-3

Signs and symbols

- Railway
- Specialist Advice
- Package CF
- Package BF
- Package AF

12 December 2016

Length Scale 1:12000

0 50 100 200 300 400 m

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Cockburn Revitalisation - Freight Train Noise Impacts

Default Packages: Third Level

Figure 7-4

Signs and symbols

- Railway
- Specialist Advice
- Package CF
- Package BF
- Package AF

12 December 2016

Length Scale 1:12000

0 50 100 200 300 400 m

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Appendix A

ACCEPTABLE TREATMENT PACKAGES

The packages and information provided on the following pages are taken from a study undertaken by Lloyd George Acoustics for Freight and Logistics Council of WA.

The acceptable treatment packages are intended to simplify compliance with the noise criteria, and the relevant package should be required as a condition of development in lieu of a detailed assessment.

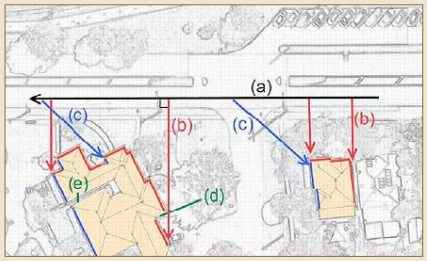
Any departures from the acceptable treatment specifications need to be supported by professional advice from a competent person that the proposal will achieve the requirements of the Policy.

With regards to the packages, the following definitions are provided, taken from SPP 5.4:

- **Facing** the transport corridor: Any part of a building façade is 'facing' the transport corridor if any straight line drawn perpendicular to its nearest road lane or railway line intersects that part of the façade without obstruction (ignoring any fence).
- **Side-on** to transport corridor: Any part of a building façade that is not 'facing' is 'side-on' to the transport corridor if any straight line can be drawn from it to intersect the nearest road lane or railway line without obstruction (ignoring any fence).
- **Opposite** to transport corridor: Neither 'side on' nor 'facing', as defined above.

Determining building face orientation

The following sketch shows two residences in proximity to a road.



'Facing' façades are identified by drawing straight lines (b) perpendicular (at a 90 degree angle) to the road (a). Where these lines intersect a façade – without obstruction – the façades are shown in red as 'facing' the road.

Façades shown in blue are not 'facing' but have clear lines (c) that intersect the road at any angle, and are therefore classed as 'side on' to the road.

The remaining façades are 'opposite' to the road.

Recommended Architectural Treatment Packages for Freight Train Noise

Area	Orientation to Road or Rail Corridor	Freight Rail Package CF (up to 92 dB L_{Amax})	Freight Rail Package BF (up to 88 dB L_{Amax})	Freight Rail Package AF (up to 80 dB L_{Amax})
All Habitable Rooms (Including Kitchens)	Facing	• Walls to $R_w + C_{tr}$ 50. • Windows and external door systems: Minimum $R_w + C_{tr}$ 34 total glazing up to 40% of room floor area. $R_w + C_{tr}$ 37 if 60%. • Roof and ceiling to achieve minimum transmission loss of 22dB at 63Hz and overall $R_w + C_{tr}$ 35 (e.g. clay roof tiles). • Mechanical ventilation.	• Walls to $R_w + C_{tr}$ 45. • Windows and external door systems: Minimum $R_w + C_{tr}$ 30 total glazing up to 40% of room floor area. $R_w + C_{tr}$ 33 if 60%. • Roof and ceiling to achieve minimum transmission loss of 22dB at 63Hz and overall $R_w + C_{tr}$ 35 (e.g. clay roof tiles). • Mechanical ventilation.	• Walls to $R_w + C_{tr}$ 45. • Windows and external door systems: Minimum $R_w + C_{tr}$ 28 total glazing up to 40% of room floor area. $R_w + C_{tr}$ 31 if 60%. • Roof and ceiling to $R_w + C_{tr}$ 35. • Mechanical ventilation.
	Side	• As above.	• As above.	• As above.
	Opposite	• As above, except glazing may be 3 dB less, or % increased by 20% (i.e. $R_w + C_{tr}$ 34 for 60%).	• As above, except glazing may be 3 dB less, or % increased by 20% (i.e. $R_w + C_{tr}$ 29 for 60%).	• As above, except glazing may be 3 dB less, or % increased by 20% (i.e. $R_w + C_{tr}$ 28 for 60% or $R_w + C_{tr}$ 31 for 80%).

Example Construction for Freight Packages

Area	Orientation to Road or Rail Corridor	Freight Rail Package CF (up to 92 dB L_{Amax})	Freight Rail Package BF (up to 88 dB L_{Amax})	Freight Rail Package AF (up to 80 dB L_{Amax})
All Habitable Rooms (Including Kitchens)	Facing	• Walls: 2 x 110mm double brick wall with 50mm cavity and 50mm fibreglass insulation within the cavity. • Window: 10.5mm VLam Hush awning windows (up to 40% of room floor area). • External Doors: 10mm fully glazed hinged door (up to 20% of room floor area). • External doors to bedrooms are not recommended. • Roof and ceiling: Clay roof tiles with sarking and 10mm plasterboard ceiling, or, Colorbond roof sheeting with sarking, 4mm fibre cement sheeting fixed to the roof purlins and 2 x 10mm plasterboard ceiling. • Mechanical ventilation.	• Walls: 2 x 90mm double brick wall with 20mm cavity. • Windows: 6mm awning windows (up to 40% of room floor area); or, 10mm awning windows (up to 60% of room floor area). • External Doors: 10mm sliding glass doors (up to 20% of room floor area). • External doors to bedrooms are not recommended. • Roof and ceiling: Clay roof tiles with sarking and 10mm plasterboard ceiling, or, Colorbond roof sheeting with sarking, 4mm fibre cement sheeting fixed to the roof purlins and 2 x 10mm plasterboard ceiling. • Mechanical ventilation.	• Walls: 2 x 90mm double brick wall with 20mm cavity. • Windows: 6mm awning or 10mm sliding windows (up to 40% of room floor area); or, 6mm awning windows (up to 60% of room floor area). • External Doors: 6mm sliding glass doors (up to 20% of room floor area). • Roof and ceiling: Colorbond roof sheeting with 10mm plasterboard ceiling. • Mechanical ventilation.
	Side	• As above.	• As above.	• As above.
	Opposite	• As above, except - • Windows: 6mm awning windows (up to 40% of room floor area); or, 10mm awning windows (up to 60% of room floor area). • External Doors: 6mm fully glazed hinged door (up to 20% of room floor area).	• As above, except - • Windows: 6mm awning or 10mm sliding windows (up to 40% of room floor area); or, 6mm awning windows (up to 60% of room floor area). • External Doors: 6mm sliding glass doors (up to 20% of room floor area).	• As above, except - • Windows: 4mm awning or 6mm sliding windows (up to 40% of room floor area); or, 6mm awning or 10mm sliding windows (up to 60% of room floor area).
Outdoor Living Area		• Where practicable, locate an outdoor living area on the opposite side of the rail corridor or in an alcove on the side of the house.	• Where practicable, locate an outdoor living area on the opposite side of the rail corridor or in an alcove on the side of the house.	• Where practicable, locate an outdoor living area on the opposite side of the rail corridor or in an alcove on the side of the house.

Appendix B

Terminology

The following is an explanation of the terminology used throughout this report.

Decibel (dB)

The decibel is the unit that describes the sound pressure and sound power levels of a noise source. It is a logarithmic scale referenced to the threshold of hearing.

A-Weighting

An A-weighted noise level has been filtered in such a way as to represent the way in which the human ear perceives sound. This weighting reflects the fact that the human ear is not as sensitive to lower frequencies as it is to higher frequencies. An A-weighted sound level is described as L_A dB.

L_1

An L_1 level is the noise level which is exceeded for 1 per cent of the measurement period and is considered to represent the average of the maximum noise levels measured.

L_{10}

An L_{10} level is the noise level which is exceeded for 10 per cent of the measurement period and is considered to represent the "*intrusive*" noise level.

L_{90}

An L_{90} level is the noise level which is exceeded for 90 per cent of the measurement period and is considered to represent the "*background*" noise level.

L_{eq}

The L_{eq} level represents the average noise energy during a measurement period.

$L_{A10,18hour}$

The $L_{A10,18\ hour}$ level is the arithmetic average of the hourly L_{A10} levels between 6.00 am and midnight. The *CoRTN* algorithms were developed to calculate this parameter.

$L_{Aeq,24hour}$

The $L_{Aeq,24\ hour}$ level is the logarithmic average of the hourly L_{Aeq} levels for a full day (from midnight to midnight).

$L_{Aeq,8hour}$ / $L_{Aeq\ (Night)}$

The $L_{Aeq\ (Night)}$ level is the logarithmic average of the hourly L_{Aeq} levels from 10.00 pm to 6.00 am on the same day.

$L_{Aeq,16hour}$ / $L_{Aeq\ (Day)}$

The $L_{Aeq\ (Day)}$ level is the logarithmic average of the hourly L_{Aeq} levels from 6.00 am to 10.00 pm on the same day. This value is typically 1-3 dB less than the $L_{A10,18hour}$.

R_w

This is the weighted sound reduction index and is similar to the previously used STC (Sound Transmission Class) value. It is a single number rating determined by moving a grading curve in integral steps against the laboratory measured transmission loss until the sum of the deficiencies at each one-third-octave band, between 100 Hz and 3.15 kHz, does not exceed 32 dB. The higher the R_w value, the better the acoustic performance.

C_{tr}

This is a spectrum adaptation term for airborne noise and provides a correction to the R_w value to suit source sounds with significant low frequency content such as road traffic or home theatre systems. A wall that provides a relatively high level of low frequency attenuation (i.e. masonry) may have a value in the order of –4 dB, whilst a wall with relatively poor attenuation at low frequencies (i.e. stud wall) may have a value in the order of -14 dB.

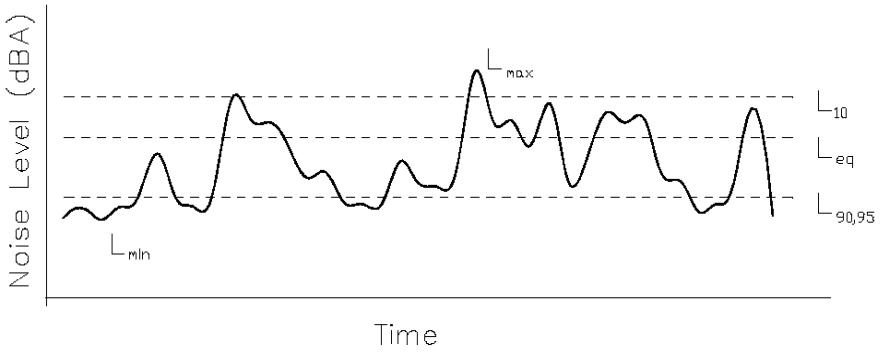
Satisfactory Design Sound Level

The level of noise that has been found to be acceptable by most people for the environment in question and also to be not intrusive.

Maximum Design Sound Level

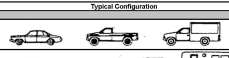
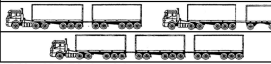
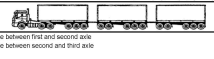
The level of noise above which most people occupying the space start to become dissatisfied with the level of noise.

Chart of Noise Level Descriptors



Austroads Vehicle Class

AUSTROADS Vehicle Classification System

Level 1 Length (indicative)	Level 2 Axles and Axle Groups		Level 3 Vehicle Type	AUSTROADS Classification		
Type	Axles	Groups	Typical Description	Class	Parameters	Typical Configuration
			LIGHT VEHICLES			
Short up to 5.5m		1 or 2	**Short** Sedan, Wagon, 4WD, Utility, Light Van, Bicycle, Motorcycle, etc	1	d(1) < 3.2m and axles = 2	
Medium 5.5m to 14.5m **Long** 11.5m to 19.0m **Medium Combination** 17.5m to 36.5m **Large Combination** Over 33.0m	3, 4 or 5	3	**Short - Towing** Trailer, Caravan, Boat, etc	2	groups = 3 d(1) ≥ 2.1m, d(1) ≤ 3.2m, d(2) ≥ 2.1m and axles = 3, 4 or 5	
			HEAVY VEHICLES			
	2	2	**Two Axle Truck or Bus**	3	d(1) > 3.2m and axles = 2	
	3	2	**Three Axle Truck or Bus**	4	axles = 3 and groups = 2	
	> 3	2	**Four Axle Truck**	5	axles > 3 and groups = 2	
	3	3	**Three Axle Articulated** Three axle articulated vehicle, or Rigid vehicle and trailer	6	d(1) > 3.2m, axles = 3 and groups = 3	
	4	> 2	**Four Axle Articulated** Four axle articulated vehicle, or Rigid vehicle and trailer	7	d(2) < 2.1m or d(1) < 2.1m or d(1) > 3.2m axles = 4 and groups > 2	
	5	> 2	**Five Axle Articulated** Five axle articulated vehicle, or Rigid vehicle and trailer	8	d(2) < 2.1m or d(1) < 2.1m or d(1) > 3.2m axles = 5 and groups > 2	
	≥ 6	> 2	**Six Axle Articulated** Six axle articulated vehicle, or Rigid vehicle and trailer	9	axles = 6 and groups > 2 or axles = 6 and groups = 3	
	> 6	4	**B Double** B Double, or Heavy truck and trailer	10	groups = 4 and axles > 6	
	> 6	5 or 6	**Double Road Train** Double road train, or Medium articulated vehicle and one dog trailer (M.A.D.)	11	groups = 5 or 6 and axles > 6	
	> 6	> 6	**Triple Road Train** Triple road train, or Heavy truck and three trailers	12	groups > 6 and axles > 6	

Definitions: Group: Axle group, where adjacent axles are less than 2.1m apart
Groups: Number of axle groups
Axles: Number of axles (maximum axle spacing of 10.0m)
d(1): Distance between first and second axle
d(2): Distance between second and third axle

Typical Noise Levels